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ORIGINAL ARTICLES.

I.—Arrangement of the Leaves in the Australian Species of *Noeggerathiopsis*.[1]

By R. Etheridge, jun., Director and Curator of the Australian Museum, Sydney.

With a Postscript by Professor A. C. Seward, M.A., F.R.S., Professor of Botany in the University of Cambridge.

(PLATE XIII.)

In 1849 Professor J. D. Dana described certain leaves from the Illawarra District and Newcastle, New South Wales, occurring in the Upper Coal-measures. To these he gave the name of *Noeggerathia spathulata* and *N. media*.[2] Long after, in 1879 to be exact, Dr. O. Feistmantel established his genus *Noeggerathiopsis* for the reception of similar leaves from the Talchir-Kararbari Beds of the Lower Gondwana System,[3] and from his remarks it may, by inference, be concluded that Dana's were included in the new genus also. This inference is justified by Feistmantel's later definite reference of these leaves to *Noeggerathiopsis*;[4] at the same time he added another species, *N. prisca*, from the Lower Coal-measures at Greta. He believed them to be closely allied with Cycadeaceæ.

It is not my intention to follow step by step the various suggestions advanced on the systematic position of *Noeggerathiopsis*, nor express an opinion on the vexed question of specific identity of the leaves; suffice it to quote Dr. E. A. N. Arber's summing up: "Considerable difference of opinion has existed both with regard to the affinities of this genus and also in respect to the identity of some of its members. The first Indian specimens were described by Bunbury in 1861, who referred them provisionally to the Gymnospermous genus *Noeggerathia*. This generic name was also at one time adopted by Feistmantel . . . The same author, in 1881, pointed out the close similarity presented by the leaves described as *Rhiptozamites*, by Schmalhausen, with the

[1] *Noeggerathiopsis* = *Rhiptozamites*, Schmalhausen (Mém. Acad. Imp. Sci. St. Petersb., xxvii (7), No. 4, 1879). This identity is admitted by Schenk (Zittel's *Handbook Pal.*, ii, Palæoph., p. 330, f.n.); Kurtz (*Revista Museo la Plata*, v, p. 130, 1894); Arber (Quart. Journ. Geol. Soc., lviii, p. 19, 1902); Kurtz (Quart. Journ. Geol. Soc., lix, p. 25, 1903).

[2] Dana, Wilkes U.S. Explor. Exped., Geol. x, p. 715, pl. xii, figs. 9, 10, 1849.

[3] Feistmantel, "Foss. Flora Gondwana Syst." (*Pal. Indica*), iii, pt. i, p. 23, 1879.

[4] Feistmantel, *Palæontographica*, Supp. Bd. iii, Lief. iii, Heft ii, pp. 158, 162, 1879.

Indian and Australian species of *Noeggerathiopsis*, and the probable affinity of both these genera to the Mesozoic Cycads of the family Zamiæ.

"In more recent times, Zeiller, Seward, Solms-Laubach, and others have regarded this genus as in all probability a member of the Cordaitales, closely allied to *Cordaites* . . .

"Zeiller has made a careful study of the leaves described by Schmalhausen as *Rhiptozamites*. He regards them as belonging to a true *Cordaites*, and as distinct from the members of the Glossopteris flora described here, which, however, they closely resemble in several respects . . .

"Zeiller has pointed out that the constant occurrence of Cordaitean seeds of the genera *Cardiocarpus* or *Cardaicarpus* in association with *N. Hislopi*, is an additional argument in favour of referring *Noeggerathiopsis* to the Cordaitales." [1]

One of Dana's figures exhibits a number of leaves "proceeding from a common base, as if the cluster of leaves growing together, and perhaps at the extremity of a branch . . . In this cluster, which is evidently a natural group, the leaves are of different ages . . . The centre from which the leaves radiate has a shining coaly aspect, as if a soft bud or vegetable base of some thickness had been pressed down and carbonized".[2] On the piece of shale figured there are two such groups.[3]

These illustrations of Dana's do not seem to have attracted the attention of palæobotanists to the extent one would have expected. As a matter of fact, I do not remember any direct reference to them other than that of Tenison Woods,[4] although I think it may be accepted that Arber's interesting figure[5] of a specimen in the Clarke Collection at Cambridge, and named by McCoy *Zeugophyllites elongatus*, but not of Morris, "a group of three leaves which appear to radiate from some axis unfortunately missing," is of the same nature. I am pleased, therefore, to be now able to supplement Dana's illustrations by an account of four clusters, more or less complete.

In Dana's fig. 9 there are portions of nine or ten leaves (it is difficult to say how many exactly on the lower side of the figure) varying from obtusely spathulate to lanceolate-spathulate, but all narrowed at the base. At the right-hand side of the hand-specimen is the other fragmentary cluster, but in this instance there is one entire leaf and traces of three or four others. Unfortunately, these figures do not afford any evidence of the phyllotaxis, whether these leaves were in their order spiral, fascicled, or verticillate, or of their method of attachment, amplexicaul, articulate, or even subamplexicaul. Dana's suggestion of a cluster of leaves growing at the end of a branch to some extent suggests a fascicular arrangement, a suggestion I return to later.

[1] Arber, *Cat. Foss. Plants Glossopteris Flora Brit. Mus.*, pp. 178–9, 1905.
[2] Dana, Wilkes, U.S. Explor. Exped., Geol. x, p. 715, 1849.
[3] Dana, ibid., pl. xii, fig. 9.
[4] Ten. Woods, Proc. Linn. Soc. N.S. Wales, iii, pt. i. p. 117, 1883.
[5] Arber, Quart. Journ. Geol. Soc., lviii, p 18, pl. i, fig. 1, 1902.

We may now turn to the further examples of *Noeggerathiopsis* leaves. On the specimen illustrated in Plate XIII are two clusters more or less imperfect, but in both instances the leaves, such as they are, radiate from a centre, the latter representing Dana's "soft bud, or vegetable base". In Fig. 1 of this Plate there are seven leaves, or portions thereof, lanceolate-spathulate, the terminations of four in which the apices are preserved, acute, and pointed. The second example on this same block of stone is smaller and much less perfect, with portions of six or seven leaves, of which the two most complete have rounded apices.

The most complete specimen (Pl. XIII, Fig. 2) is on a separate piece of matrix and displays no less than at least nine leaves or portions. Here there are certainly two in which the apices are obtusely rounded, giving to the leaves a more or less elongately pyriform or club-shaped outline. On a continuation of this same piece of matrix is a small third cluster in which five leaves are preserved, all with angular apices, but the apical portions are shorter than in Pl. XIII, Fig. 1. On the reverse of this specimen of shale occurs the fourth cluster, which consists of the remains of four, or perhaps five leaves, also radiate.

The substance of these leaves is thick, coriaceous, and black in colour, in both examples on the large hand-specimen, whilst the three on the smaller are matrix impressions with the venation apparent. These leaves are petiolate, as described by Arber, and in one of the smaller and less complete examples this petiolate attachment is fairly apparent.

There are now six instances of this radiate arrangement of leaves in *Noeggerathiopsis* known, and if Arber's illustration is of the same nature (and I have very little doubt it is so), there is then a seventh, viz. two by Dana, and the four here described in which the leaves are spread out in a circle, radiate from a common centre, and in each instance present what, I believe, is the deceptive appearance of being on the same plane with one another. It is remarkable that, in the six instances, the mode of preservation is precisely the same.

It is at first difficult to obliterate from one's mind the idea of a verticillate arrangement of these leaves, but if we devote a little consideration to the phyllotaxis of *Cordaites*, an explanation of this radiate arrangement will, I think, be forthcoming, for we must not lose sight of the strong consensus of opinion that *Cordaites* and *Noeggerathiopsis*, if not identical, are most nearly related, Professor Seward even saying, in 1907: "I prefer to adopt the generic name *Cordaites* in preference to that of *Noeggerathiopsis* on the ground that *Noeggerathiopsis* is probably not distinct from the widely distributed northern type." [1]

[1] Seward, Rec. Geol. Surv. India, xxvi, pt. i, p. 60, 1907. The close affinity of the two genera in question is supported by Zeiller, 1882 (Ann. Mines, Livr. Sept.–Oct. 1882); Schenk, 1890 (Zittel's *Handb. Pal.*, Abth. ii, p. 330, footnote); Kurtz, 1894 (*Revista Museo de la Plata*, v, pp. 130–1, 1894); White, 1908 (*Com. Estudos Minas Brazil, Relatorio final*, 1908, pt. iii, p. 546); Krasser, 1909 (Jahrb. Geol. Reichst. Wien, lix, Heft i, p. 121, 1909); Seward, 1907 (Rec. Geol. Surv. India, xxxvi, pt. i, p. 60, 1907); Seward, 1907 (Trans. Geol. Soc. S. Africa, x, p. 707, 1907).

One of F. C. Grand-Eury's figures[1] of *Cordaites lingulatus* displays the terminal leaves of a branch bunched together or clustered, and more or less subimbricate. By exerting downwards an expanding pressure upon such a clump, when in the fresh state, a star-like disposition, such as we have presented to us in *Noeggerathiopsis*, would, in all probability, be the result. What appears to be an improved copy of Grand-Eury's figure is given by Renault.[2] A similar terminal clustering is also visible in the former author's figure of *Dory-Cordaites*.[1]

If this cluster method of leaf arrangement be admitted in *Noeggerathiopsis* it at once lends support to the accuracy of Zeiller's reference to it of certain leaf-bearing branch portions, with leaf-scars found in the Coal-measures of Tong-Kin. He remarked as follows: "D'empreintes correspondant à de petits fragments de rameaux, et portant des cicatrices foliaires très analogues à celles des *Cordaicladus*, marquées chacune de plusieurs cicatricules ponctiformes, disposées les unes à la suite des autres sur un arc parallèle au bord supérieur de la cicatrice."[3]

No other example of *Noeggerathiopsis* leaves preserved in this condition, other than those now recorded, has been found in the Upper Coal-measures of New South Wales so far as I am aware. Referring to an occurrence of stems similar to that recorded by Zeiller, Mr. L. Lesquereux[4] said "fragments of ribbon-like leaves rarely found in connexion with the stems".

The leaves of *Cordaites* are said by authorities to be spirally arranged on a branch, but a very strange and remarkable form is figured by Lesquereux as *Cordaites radiatus*.[5] He wrote: "Leaves short, narrow, linear, obtuse, placed in right-angle and star-like around the stems." His fig. 5 is "part of a stem covered by leaves horizontally diverging, so that each section of the stem shows them placed exactly like the rays of a star". Lesquereux's expressions are not too clear; does he wish it to be inferred that the phyllotaxis is verticillate? The figures certainly have such an appearance. Or, is it an instance of a clump pressed down from above, as I have suggested to account for the radiate arrangement of the leaves in *Noeggerathiopsis*?

Locality.—Fig. 1. Mount Kembla, Illawarra. Collected by W. A. Cuneo. Fig. 2. Mount Kembla. Collected by C. Cullen.

Horizon.—Upper Coal-measures (Permo-Carboniferous).

EXPLANATION OF PLATE XIII.

Leaves of *Noeggerathiopsis*.

FIG. 1.—Seven leaves radiating from a common centre, lanceolate-spathulate, four of the more complete with acute apices.

,, 2.—Another example, with at least nine leaves radiate and more symmetrically arranged than in Fig. 1; two appear to have obtusely rounded apices.

[1] Renault, Cours Bot. Foss., i, pl. xii, fig. 1, 1881.

[2] Grand-Eury, loc. cit., pl. xviii, fig. 8.

[3] Zeiller, Ann. des Mines, 1882, Sept.-Oct., p. 26 (separate copy).

[4] Lesquereux, Descrip. Coal Flora Carb. Form. Pennsylvania (Second Geol. Surv. Penn., Report Progress, P), i, p. 525, 1880.

[5] Lesquereux, loc. cit., p. 540, pl. lxxxvii, figs. 5, 6.

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LEAVES OF *NŒGGERATHIOPSIS*.

Coal Measures. New South Wales.

[*Postscript.*—The Australian leaf-clusters figured by Mr. Etheridge bear a very close resemblance to an Indian specimen reproduced in vol. iii (p. 242, fig. 472) of my *Fossil Plants*, which shows leaves attached in a close spiral to a supporting axis.

The late Miss Ruth Holden detected certain differences similar to those pointed out by Professor Zeiller in the stomatal arrangement on *Noeggerathiopsis* leaves from India as compared with that on English leaves of *Cordaites*, but the results were not published (*Fossil Plants*, vol. iv, pp. 243–4). Mr. Sahni, of Emmanuel College, Cambridge, who has made a further examination of cuticular preparations, hopes in the near future to make a contribution to this subject.—A. C. Seward.]

II.—The Genesis of Tungsten Ores.

By R. H. Rastall, M.A., F.G.S.

(*Continued from the June Number, p. 246.*)

Part III: Scheelite Deposits.

From the descriptions already given, and from a general survey of the literature of the subject, it is apparent that scheelite is a frequent associate of wolframite in the lodes of magmatic origin. In fact, a certain number of the occurrences already cited, especially in the second part of this paper, might almost as well have been described as scheelite deposits, since the two minerals are found in something like equal quantities. This applies, for example, to a large number of the American and Canadian occurrences, to those of the Malay States, and others. This is only to be expected from general considerations, since gases or solutions containing chemically active tungsten compounds coming in contact with calcareous material would naturally tend to form calcium tungstate. The same applies to lead-bearing minerals; hence in a few instances lead tungstate, stolzite, has been found in association with scheelite. It is of interest to note that scheelite often contains from 1 to 3 per cent of molybdenum. Wolframite and scheelite are often found in lodes and other masses very closely intergrown, and in many cases there is evidence of much pseudomorphism. In some cases scheelite has clearly replaced wolframite, while in other cases the reverse holds. The law governing the paramorphism of these minerals is somewhat obscure, and it is not easy to say anything definite on the subject. In this direction further investigation is required, although the point is not perhaps of much practical importance.

With regard to the predominance of wolframite or scheelite in any particular district, the general rule seems to be that wherever the country rock is more or less calcareous scheelite tends to form; that this would naturally be so is of course obvious, and the subject hardly seems to need much further elaboration. The general aspect of the problem can be more satisfactorily discussed after consideration of certain deposits in which scheelite is the dominant or even the only tungsten ore present, since such do occur in various parts of the world.

Although scheelite occurs along with wolframite in Cornwall it is only in small quantity and of no practical importance. The only workable scheelite deposit known in the British Isles is at Grainsgill in Cumberland, on the north-eastern side of the Skiddaw area. Here the lodes are highly mineralized quartz veins connected with the pneumatolytic phase of the Skiddaw granite; they are in close association with the greisen of Grainsgill, which is certainly a differentiation product of the granite magma. Unfortunately a good deal of uncertainty still exists as to the relation of the lodes to the surrounding rocks, and especially to the gabbro and granophyre of Carrock Fell. This is a very important point in relation to the age of the latter, which is a matter of dispute. The minerals found in association with the scheelite ores are molybdenite, arsenopyrite, pyromorphite, galena, blende, native bismuth, bismuth telluride (with a little gold), and tourmaline, while crystals of fluorite have been observed in joint planes in the greisen; it is notable also that arsenopyrite occurs in considerable quantity in the same rock. It is not known whether the lead-zinc-bismuth minerals are contemporaneous with the quartz and wolfram minerals or whether they belong to a later phase of mineralization related to the post-Carboniferous lead-zinc deposits of the North of England. The presence of tourmaline and fluorite indicates pneumatolytic influences, and in any case the genetic connexion with the Grainsgill greisen seems clear.[1]

In Spain and Portugal scheelite is found together with wolframite in many of the deposits. At the La Sorpresa mine in the province of Cordoba it occurs in this way in quartz veins, running from granite into slate, and the ores tend to occur especially at the junction of the two rocks. This fact appears to bring them into the category of contact deposits. In a somewhat similar way scheelite is found in Haute Vienne, France,[2] in veins with wolframite, cassiterite, molybdenite, arsenopyrite, and pyrite in a gangue of quartz. This is an example of its occurrence in the normal tin-wolfram lode type.

An interesting occurrence of scheelite with cassiterite is found at Pitkäranta in Finland, to the north of Lake Ladoga.[3] Here gneisses and schists containing beds of limestone are intruded by Rapakiwi granite, and it is in the limestones that the ores principally occur. The ores include three principal types: (1) magnetite, (2) copper ore, and (3) tin-scheelite ore. All the ores are intergrown with a remarkable variety of contact-metamorphic calcareous minerals, including diopside, garnet, vesuvianite, chondrodite, and calcite. Topaz and fluorite have also been observed in small quantity. This is a particularly instructive case, since here, where the ores are so closely associated with limestone, scheelite is found without

[1] Finlayson, GEOL. MAG., 1910, p. 19. *The Mineral Resources of Great Britain*, vol. i: "Tungsten and Manganese Ores" (Mem. Geol. Surv.), 1916, p. 3.

[2] Huré, Bull. Soc. Industrie Minérale, vol. ix, p. 99.

[3] Trüstedt, "Die Erzlagerstatten von Pitkäranta am Ladogasee": Bull. Comm. Geol. Finlande, 1907, No. 19.

wolframite. The mineralization is clearly pneumatolytic, as shown by the occurrence of greisen and fluorine-bearing minerals. It is evident that calcium carbonate was abundant in the country rock and the tungsten compounds of the intrusive magma combined with the calcium rather than with iron; that iron was abundantly present is proved by the fact that the iron ores are demonstrably older than the tin ores. This case shows certain affinities with the occurrence at Trumbull, Connecticut, already referred to at some length. The ore-deposits at Pitkäranta are certainly of metamorphic origin, being referable to the intrusion of the Rapakiwi granite, and the metamorphism is equally clearly of pneumatolytic character; the action was selective, and the tungsten-bearing vapours or solutions combined by preference with lime rather than iron.

As before stated, scheelite occurs in many parts of Canada; a good example is afforded by the scheelite mine near the Moose River gold-mines in Halifax County, Nova Scotia.[1] The country rock consists of highly folded and cleaved quartzites and slates. The veins containing the scheelite are similar to the gold-bearing veins in the adjoining gold-mines. They contain quartz, felspar, mica, tourmaline, arsenopyrite, and carbonates (calcite and ankerite). The scheelite is concentrated mainly at the top of anticlines or in the troughs of synclines. These mineralized veins are accompanied by veins of pure quartz of apparently later date. The mineral veins appear to be essentially pegmatitic in their nature, as shown by the presence of felspar and mica. The non-mineralized quartz veins probably represent a later differentiate from the same source.

In the Yukon Territory scheelite has been known for some time as a heavy concentrate obtained in gold-washing, and the mineral has lately been located in lodes in the neighbourhood of Dublin Gulch. It occurs in small quartz veins, which themselves intersect zones of pegmatite within the granite. Wolfram and tinstone also occur in small quantities.

At the present time the world's greatest producer of scheelite is California. The Atolia mining district, in the Mohave Desert, on the borders of San Bernardino and Kern Counties, in 1916 shipped 1,831 tons of scheelite concentrates, carrying on an average 60 per cent of tungsten trioxide. A large part of this ore is obtained from alluvial deposits, where it is found in lumps up to 100 lb. in weight, but it is also worked to a considerable extent in lodes. These lodes are as a rule more or less continuous fissures in granite, but in some places they appear to be associated with small basic dykes cutting the granite, while in other places the scheelite is found in metamorphosed limestones at or near the granite contact, associated with garnet, epidote, and other metamorphic minerals. The lodes proper consist of scheelite with a gangue of quartz; they run up to 3 feet in width, and have been followed to a depth of 700 feet. In other parts of Kern County scheelite occurs in bunches in gold veins, and as nearly pure stringers cutting through slate; also in veins in granite with amphibole, pyroxene, garnet, sphene, and oxidized

[1] Report of the Geological Survey of Canada, Department of Mines, for the year 1916, Ottawa, 1917, p. 249.

copper minerals, as well as in pegmatites with quartz, oligoclase, and muscovite.[1] The general association of the scheelite deposits of California is with siliceous gold veins in connexion with granites. This shows a distinct resemblance to the wolfram-gold association of Boulder County, Colorado, but in California more lime is present in the rocks, and therefore scheelite has been formed instead of wolfram.

In the Federated Malay States scheelite occurs in considerable quantity in addition to wolframite. A particularly interesting case has been noticed at Salak.[2] It is a lode about 12 feet wide, consisting of scheelite, quartz, and light-yellow tourmaline, with traces of arsenic and copper. Another scheelite vein also contained fluorite and axinite with a little quartz. There are several other instances of scheelite lodes all apparently more or less closely associated with granite-limestone contacts. The mineral is also found to a small extent in the gold veins of the Raub mines, where the country rock is distinctly calcareous in character.

Summary of Part III.

It would be easy to give many more examples of the occurrence of scheelite in situ in lodes, veins, and contact deposits, but it is doubtful if any good purpose would be served by so doing. Enough has been said to show that in very many cases scheelite is found as a lode mineral either with or without wolframite. It is also a frequent product of contact metamorphism of granites intruded into or near limestones. This metamorphism is of the type commonly, though perhaps unnecessarily, called pneumatolytic. A regular gradation can be traced from the tin-wolfram deposits, through the wolfram deposits without tin to the scheelite lodes. This transition is on the whole accompanied by a falling-off in the amount of the paragenetic molybdenum and arsenic sulphides and the minerals of the fluorine-boron group, but in certain instances tourmaline and fluorite are found to survive into the scheelite lodes. The genetic connexion between scheelite and siliceous gold veins is also of significance.

(*To be concluded in the next Number.*)

III.—On the Pre-Thanetian Erosion of the Chalk in parts of the London Basin.

By Herbert Arthur Baker, B.Sc., F.G.S.

IT has long been recognized that, in early Eocene times, while the "Calcaire de Mons" was being deposited in the Belgian area, large tracts of the Upper Chalk were removed by denudation from the south-east of England. The true extent of the unconformity between the Chalk and our oldest Eocene strata is now to be seen only where the Eocene cover yet remains. Even where the Chalk is

[1] *The Mineral Industry*, vol. xxiv, p. 687, 1916, and vol. xxv, p. 724, 1917; *Mining and Scientific Press*, May 27, 1916.

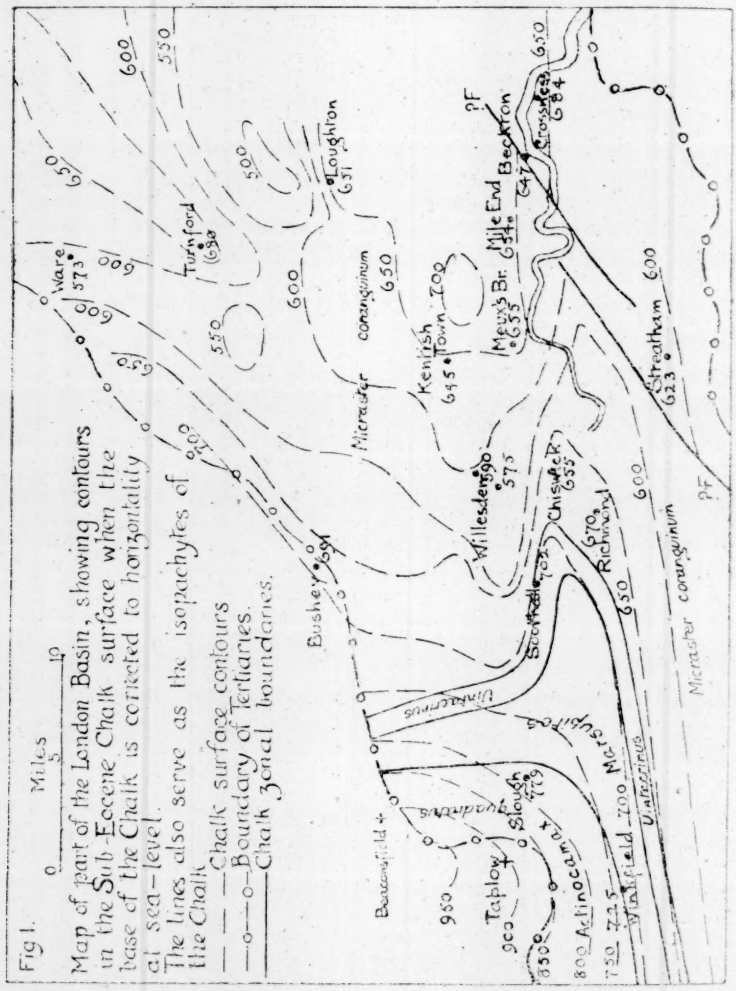
[2] Scrivenor, loc. cit., p. 7.

so covered, the unconformity must have been accentuated to some extent in consequence of the solvent action of percolating carbonated waters, the evidence of which is familiar to us as "pipes" in the Chalk filled with Eocene strata, and the persistent bed of unworn, green-coated flints ("Bull-head" Bed) which everywhere occurs between our lowest Eocenes and the Chalk; but such secondary action is likely to have been more or less uniform throughout the whole area beneath the Tertiary cover.

Thanks to the steady accumulation of data concerning well-borings and the energies of various workers who have given cartographical expression to the information thus made available, we have now a good working knowledge of the present contours of the Chalk surface within the London Basin beneath the Tertiary cover. The present configuration of this Chalk surface is, of course, widely different from that which it presented at the time of the deposition of our oldest Eocenes, in consequence of the tilting and warping effects of later movements. Nevertheless, in regard to the area within the immediate vicinity of London, we have some knowledge of the effects of these post-Cretaceous movements upon the Chalk formation, since here a number of deep borings have completely pierced the Chalk, thus affording us information as to the present level of its base. We are therefore in a position to apply a "correction", so as to reduce the base of the Chalk to a horizontal plane, and, having done this, to observe the form which the contours of the Chalk surface then take. If the correction be applied so as to cause the base of the Chalk to occupy a horizontal plane at present sea-level, the resulting surface-contours are then also the "isopachytes" or lines of equal thickness of the formation.

The movement of elevation which set in towards the end of Cretaceous times and ushered in the Tertiary era appears to have been a widespread and regional one, and it is reasonable to assume that in the area under present consideration the base of the Chalk, at the beginning of Tertiary times, did not deviate widely from horizontality. Consequently the contours of the Chalk surface beneath the Eocene cover, when the base of the formation has been corrected to horizontality, may fairly be regarded as giving an approximately true representation of the configuration of the surface upon which our oldest Eocenes were deposited.

In order to obtain these pre-Thanetian contours of the Chalk surface we proceed as follows: We first plot upon the map the sites of the deep borings (seventeen in number) which have completely pierced the Chalk formation in the area under consideration, inserting in each case the depth below Ordnance Datum at which the base of the Chalk occurs. We then draw in the present contours in the base of the Chalk at intervals of 100 feet, working upon the available data, and assuming an even gradient between any boring and its neighbours. The total number of borings not being large, the trend of the lines is doubtless influenced somewhat unduly by the accidents of boring sites, but fortunately the sites are fairly evenly distributed throughout the area, and the error involved is not serious. Having prepared this map, we superimpose upon it the map of the same area



showing the present contours in the sub-Eocene Chalk surface.[1] The first map indicates the amount of correction to be applied to the base of the Chalk at any point in order to bring it to horizontality at present sea-level, and the superimposed map is corrected correspondingly. For example, the points at which the O.D. contour of the superimposed map intersects the −600 contour of the base of

[1] In this investigation the writer has used the map of the Pre-Tertiary Chalk surface prepared by Mr. L. J. Wills (*Records of London Wells*, Mem. Geol. Surv., 1913) and also that by Professor P. G. H. Boswell (Q.J.G.S., vol. lxxi, pl. L).

the Chalk are points on the 600 contour of the corrected Chalk surface. Similarly, points at which the —200 contour of the present Chalk surface intersects the —700 contour of the base of the Chalk are points on the 500 contour of the corrected surface, and so on. By joining up the similarly numbered points so obtained, the contour system of the corrected pre-Tertiary Chalk surface is arrived at (see Map 1). The numbers appended to the contours possess only a relative significance. The base of the Chalk might have been corrected so as to cause it to occupy any horizontal plane, but by selecting present sea-level as the datum-plane we have the additional advantage that the lines serve equally well as the isopachytes of the Chalk formation.

A glance at the map reveals at once that the information afforded by it well repays the labour involved in its preparation. It appears that the age of the Streatham–Beckton fault is pre-Tertiary, and from the form of the lines in the neighbourhood of Loughton we may suspect faulting here also.

The first significant fact which the map brings out with great clearness is that in pre-Tertiary times the Chalk of this area was denuded in such a way as to produce escarpments facing inwards towards the centre of the present London Basin, thus indicating plainly that the central area experienced a somewhat greater uplift and suffered greater denudation than the district farther west. With the exception of a small area between Kentish Town and Mile End, where the Chalk has probably been protected by faulting, it is a noteworthy fact that the Chalk is thinnest over the area where the Gault beneath it rests directly upon the Palæozoic floor, and the general character of the pre-Tertiary denudation of the Chalk surface is in very close sympathy with the contours of the Palæozoic floor when the latter is corrected for post-Cretaceous movements.

The writer has elsewhere put forward the view that the area under present consideration lies on the south-easterly prolongation of the well-known Charnian Axis of Professor P. F. Kendall, and he inclines to the belief that the character of the pre-Tertiary denudation of the Chalk here points to the operation of Charnian posthumous movement in pre-Tertiary times. When we proceed to investigate the question of the zonal composition of the denuded Upper Chalk surface further suggestive evidence is forthcoming. At any rate, additional support is given to the statement made above that the general character of the pre-Tertiary denudation of the Chalk surface is closely associated with the pre-Cretaceous form of the Palæozoic floor.

In endeavouring to insert upon the map the positions of the boundaries of the zonal outcrops beneath the Eocene cover we are at once confronted with the difficulty that we have as yet little knowledge of the thicknesses of the various zones of the Upper Chalk in and near this area. It has been possible, in the case of some of the borings, from the details given in the journal, to effect the division between Lower, Middle, and Upper Chalk, and sometimes horizons easily recognizable lithologically, such as the Melbourn Rock and the Chalk Rock, can be identified. Apart from this we

are dependent upon the information forthcoming from workers who have studied the Chalk of neighbouring districts. It is fairly certain, however, that except in the west the whole of the sub-Eocene surface of the area under present consideration is occupied by the outcrop of the thick zone of *Micraster coranguinum*. At Crossness the Chalk proved to be 684 feet thick, but the Chalk exposed to view in the Woolwich district, not far away, is, to the writer's personal knowledge, clearly referable to the *M. coranguinum* zone. Of the 654 feet of Chalk occurring at Mile End, 259 feet were assigned to the Upper Chalk, and, since allowance must be made for the Chalk Rock and the *M. cortestudinarium* zone, it is not likely that any higher horizon than that of *M. coranguinum* occurs here. Even in the case of the 700 feet of Chalk which occurs between Kentish Town and Mile End the statement still holds good. If we take the thicknesses of the Lower and Middle Chalk as recorded at Mile End, allow only 10 feet for the Chalk Rock and 50 feet for the zone of *M. cortestudinarium*, we are left with 225 feet of Chalk, and it is hardly likely that the *M. coranguinum* zone is much less than this in thickness.

Where the Chalk decreases to 500 feet in thickness, as it does between Loughton and Turnford, the question arises as to whether the *M. cortestudinarium* zone there composes the sub-Eocene surface. At Turnford 406 feet were assigned to the Lower and Middle Chalk and 15 feet to the Chalk Rock. Allowing 50 feet for the *M. cortestudinarium* zone, we are still left with about 30 feet of *M. coranguinum* Chalk. Hence, as already remarked, it is fairly certain that except in the west the whole of the sub-Eocene Chalk surface of our area is occupied by the outcrop of *M. coranguinum* Chalk.

But in the west a different state of affairs obtains. Here the Chalk reaches a thickness of as much as 950 feet in the neighbourhood of Beaconsfield, and 900 feet a little further south at Taplow. In this neighbourhood two deep wells have completely pierced the Chalk, one at Slough and the other at Winkfield. With regard to the first, beyond the fact that the Chalk was found to have a thickness of 778 ft. 10 in., no further particulars concerning the formation appear to be available. But in the case of the Winkfield well we are more fortunately situated. A full account of this has been published,[1] and we are in possession of the information that the Lower Chalk was 219 feet thick, the Middle Chalk 169 feet, the Chalk Rock 8 feet, and the Upper Chalk 329 feet. Turning now to other authorities for information, we find that Mr. H. J. Osborne White[2] suggests 50 feet as the thickness of the *M. cortestudinarium* zone and 220 feet as that of the *M. coranguinum* zone in this area. Adopting these figures, we find that at Winkfield we get 666 feet as the thickness of the Chalk from the base of the formation to the base of the *Marsupites* zone, thus leaving 59 feet of Chalk for the latter

[1] *Water Supply of Berkshire* (Mem. Geol. Surv.), 1902, pp. 95–6.

[2] "Berkshire and Part of the Thames Valley": Jub. Vol. Geol. Assoc., pt. ii, 1910.

zone here. Again, fortunately we find two other conveniently situated borings supplying information which can be combined with these figures. In the well-known deep boring at Richmond Waterworks the Lower Chalk was 220 feet thick, the Middle Chalk 145 feet, the Chalk Rock 5 feet, and the Upper Chalk 300 feet. Adopting the figure of 50 feet for the thickness of the *M. cortestudinarium* zone, it is further necessary to take a figure for the thickness of the *M. coranguinum* zone at Richmond. Bearing in mind the recorded thickness of 280 feet for this zone further east in Kent, the writer adopted as a working figure 250 feet for the thickness of *M. coranguinum* Chalk at Richmond. Hence, at the latter site, the level of 670 feet above the base of the formation, for the base of the *Marsupites* zone, was arrived at. The third boring site affording information is that at Bushey (Colne Valley Waterworks), where the Lower Chalk was 255 feet thick, the Middle Chalk 267 feet, the Chalk Rock 8 feet, and the Upper Chalk 156 feet. In the absence of any evidence to the contrary the thicknesses of 50 feet for the *M. cortestudinarium* zone and 220 feet for the *M. coranguinum* zone may be taken, and the level of 800 feet above the base of the formation for the base of the *Marsupites* zone is supplied. Having now three suitably situated working levels for the base of the *Marsupites* zone, and the present map, the plotting of the concealed boundary between *M. coranguinum* and *Marsupites* Chalk becomes a simple problem in geometry. The result is indicated on the map. In view of the possibility that the figure taken for the thickness of *M. coranguinum* Chalk at Richmond (250 feet) may be a little excessive, the boundary perhaps lies a little further south between Winkfield and Richmond than is represented.

Mr. Osborne White gives 70 feet as the superior limit of thickness of the *Marsupites* zone in Berks and Bucks, and the position of the upper limiting boundary of the zone is inserted on the map in accordance with this figure. On the assumption of an average thickness of 25 feet for the *Uintacrinus* subzone the line of division of the latter from the *Marsupites* band can also be inserted.

Field-workers, in referring to the interesting development of phosphatic Chalk of the *Marsupites* zone, seen at Taplow, have stated that it is not improbable that the poorly exposed upper part of the section belongs to the succeeding zone of *Actinocamax quadratus*, although the latter has so far been identified in only two places, namely, Borough Hill, west of Winterbourne, and Kintbury, both these places being well to the west of the Taplow–Beaconsfield district. Our present map strongly suggests the existence of the *A. quadratus* zone in the latter area, and is an interesting incentive to field-workers in that district. From the figures already adopted it will be seen that a thickness of 736 feet accounts for the whole of the Chalk in this area from the base of the formation to the top of the *Marsupites* zone, and this after giving to the latter its maximum thickness of 70 feet. Consequently it follows that in the neighbourhood of Beaconsfield there is still a thickness of rather more than 200 feet of Chalk to be accounted for, and hence it appears practically certain that there the *A. quadratus* zone possesses a good thickness.

Future quarrying operations in the neighbourhood should prove interesting.

To the writer the point of greatest interest was the discovery that, as the concealed zonal outcrops approach within the sphere of influence of the ancient Charnian ridge, they suffer an abrupt change of strike and take on a northerly as well as a westerly trend. The evidence seems convincing that in this area the belt of maximum denudation of the Chalk in pre-Thanetian times possessed a N.W.–S.E. alignment, and this fact must be ascribed either to

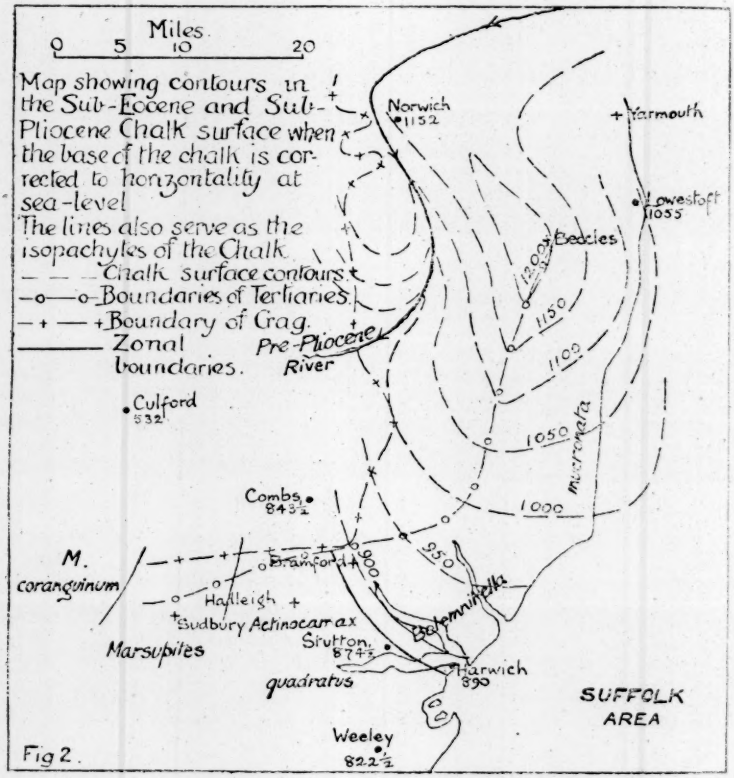


Fig 2.

the influence exerted by the form of the Palæozoic floor at that time or else to the operation of Charnian posthumous movement during the erosion of the Chalk. The area furnishing this evidence of a tendency on the part of the Chalk zonal outcrops to assume a N.W.–S.E. alignment is very small, but considering the great extent to which the erosion of the Chalk has been carried during later times, the fact that even some evidence of this tendency has been preserved to us can only be regarded as a fortunate accident.

We are, perhaps, hardly in a position to consider the question of

the precise manner in which this pre-Thanetian denudation of the Chalk was effected, but it appears likely that land existed here in Montian times and that strike streams ran at the foot of the escarpment, their direction being influenced by the presence of the ridge which proceeded from west to east by way of Southall and Chiswick. It is perhaps more than coincidence that the course of the present Thames shows a tendency to adhere to the same direction.

Interesting light is thrown on the question of the source of the material composing the Lower Eocenes of the London area. It seems clear that the material must have come from the east; it can hardly have been carried from the west over the escarpment. We have good reason to believe, too, that at this time, to the south of the present area, the Wealden uplift had already been initiated, and the interesting question is raised as to whether the denudation of the Chalk had been carried, by Thanetian times, to an extent sufficient to expose to eroding influences an adequately large area of the Lower Greensand to furnish the arenaceous material of the Lower London Tertiaries.

A simple movement of submergence appears all that is necessary to explain the overlapping of the Thanet Sand by the Reading Beds in our area, and with regard to the development of the Lower London Tertiary Pebble-beds (Blackheath Pebble-beds) in the Woolwich, Blackheath, and Bromley districts, it appears feasible to suppose that these accumulated as banks against the easterly prolongation of the Southall–Chiswick ridge.

In view of the notable scarcity of borings which have completely pierced the Chalk in Essex, we are very ignorant concerning the present level of its base in this county and are, in consequence, unable to adopt the present method of investigation here. In Suffolk we have more data to work upon, but the area of Chalk yet remaining beneath the Eocene cover is very limited for our present purpose. Nevertheless, when the base of the Chalk is corrected to horizontality, several interesting points are brought out. The Chalk surface in this county is then seen to slope away east, west, and south from an area of maximum elevation (over 1,200 feet) situated between Beccles and Bungay. This area of maximum elevation extends north-westward to a spot a little east of Norwich, and is evidently the sole relic of an elevated Chalk area which once extended much further to the west. In fact, the downward westerly slope from this district, beneath the Crag deposits, is clearly the result of post-Eocene and pre-Crag denudation of the Chalk. The southerly and easterly slopes are, however, facts of deeper significance, since these are found beneath the area where the Eocene cover yet remains. There is a drop of 200 feet between Beccles and Aldeburgh (which is only another way of saying that the Chalk is 200 feet thicker in the former place than in the latter), and hence we have in this area the last remaining evidence of the escarpment (now become very gently sloping although more elevated) which faced south-eastward and stretched away many miles to the west and south. The easterly slope of the corrected Chalk surface from Beccles to Lowestoft (or thinning of the Chalk formation in that direction) is

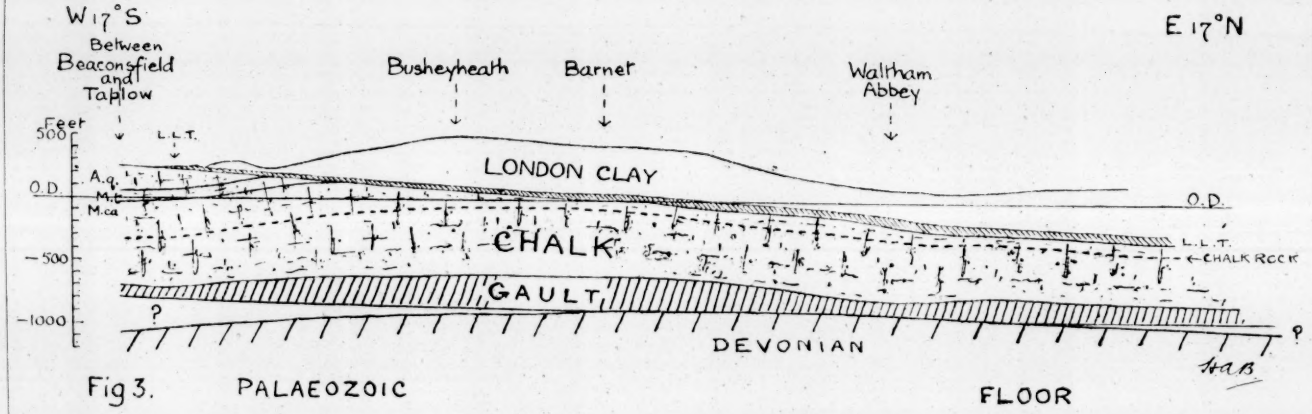


Fig 3. PALAEOZOIC FLOOR

FIG. 3.—Section across part of the London Basin, showing the unconformity between the Palæozoic and Cretaceous rocks and also that between the Cretaceous and Tertiary. Superficial deposits omitted. Vertical scale 26·4 times the horizontal scale. M.ca. = *Micraster coranguinum* zone. A.q. = *Actinocamax quadratus* zone. M.t. = *Marsupites testudinarius* zone. L.L.T. = Lower London Tertiaries.

a fact that might have been somewhat surprising if we had not been partially prepared for it. The Chalk is about 150 feet thicker at Beccles than at Lowestoft. The present writer has endeavoured to show elsewhere that this area has been affected by posthumous movements of an ancient axis which he considers to run parallel with Kendall's Charnian Axis, eastward of Kent, into North France. We notice here what we are also apparently able to detect in the London area (see section), that during the deposition of the Chalk (and possibly to some extent during the deposition of the Gault) there was a definite movement of depression along the line of the old axis whereby a somewhat greater thickness of sediment accumulated vertically above them than elsewhere. Lowestoft lies somewhat to the east of the line of the easterly axis and hence the decrease in thickness of the Chalk is accounted for. On this view it follows that a great thickness of Chalk must have been removed by denudation from the district to the north-west of Norwich, since over 1,350 feet of the formation yet remains beneath the Eocene in the neighbourhood of Mundesley and Happisburgh.

With regard to the zonal outcrops of the Chalk beneath the Eocene cover in Suffolk and Essex, the *Ostrea lunata* zone evidently does not occur here, but the line of separation of the *Belemnitella mucronata* and *Actinocamax quadratus* zones probably runs from south-east to north-west beneath the Suffolk Eocenes, meeting the coast somewhere in the neighbourhood of Harwich. After emerging from beneath the Eocenes westward of Bramford the boundary turns sharply to the north as the result of later denudation. The boundary between the *A. quadratus* and *Marsupites* zones occurs a little to the west of Hadleigh, and, beneath the Eocenes, probably sweeps off to the south-west. The same may be said of the boundary between the *Marsupites* and *M. coranguinum* zones, which occurs a little to the west of Sudbury.

In conclusion, it may be remarked that when the Chalk of Essex comes to be better known it will probably be found to be affected by a great fault stretching across the whole county from the neighbourhood of Cliffe, in Kent, to near Dunmow and Thaxted, as a result of which Chalk of the *Marsupites* zone, on the eastern side, is placed in juxtaposition with the *M. coranguinum* zone on the western side.

The section accompanying the present paper is drawn from the data supplied by maps showing contours on the Palæozoic floor, in the base of the Gault, and the base of the Chalk, prepared by the writer at various times.

IV.—On the Occurrence and Interpretation of Rock-Cliffs and Rock-Floors on the Western Shores of the "Dry" Lakes in South-Central Western Australia.

By J. T. Jutson, Geological Survey of Western Australia, Perth.

Introduction.

In South-Central Western Australia, in the physiographic division which the writer [1] has termed the Central or Salt Lake Division, in a large portion of which the average annual rainfall is about

[1] "An Outline of the Physiographical Geology (Physiography) of Western Australia": Bull. 61, Geol. Surv. W. Australia, Perth, 1914, p. 52.

10 inches per annum, numerous "dry" lakes or playas occur.[1] These have been described and the question of their origin has been discussed by various authors.[2] They have been differently regarded as due to glacial, marine, and wind action; also as the remains of old Tertiary rivers now largely obliterated by drifting sands; and also (in part) as deformation basins. Most writers agree that they have been formed under subaerial conditions, and probably most will ultimately agree that deformation is responsible for some at least of the lakes, or has aided in their formation.

The theory of a migration of the lakes has also been advanced by the present writer.

Like most other land forms the lake will probably, by further research, be shown to be due to no single cause, but to a combination of agents of different relative importance.

Summary.

This paper describes certain features of the "dry" lakes in South-Central Western Australia. These features, which repeatedly occur over a wide area, indicate, in the writer's opinion, that the lakes are migrating westward; and that wind erosion is playing the dominant part in such migration, and consequently in the present forms and position of the lakes. Such features are the presence of rock-cliffs and rock-floors on the western, north-western, south-western, and, to a less extent, on the northern sides of the lakes; and the absence of such cliffs and floors on the eastern, south-eastern, north-eastern, and southern sides of the lakes, the place of such cliffs and floors being taken by sand dunes, sand plains, and silts. The facts set forth are regarded as confirming, to some extent, the idea of the late H. P. Woodward that the "dry" lakes are due to wind action.[3]

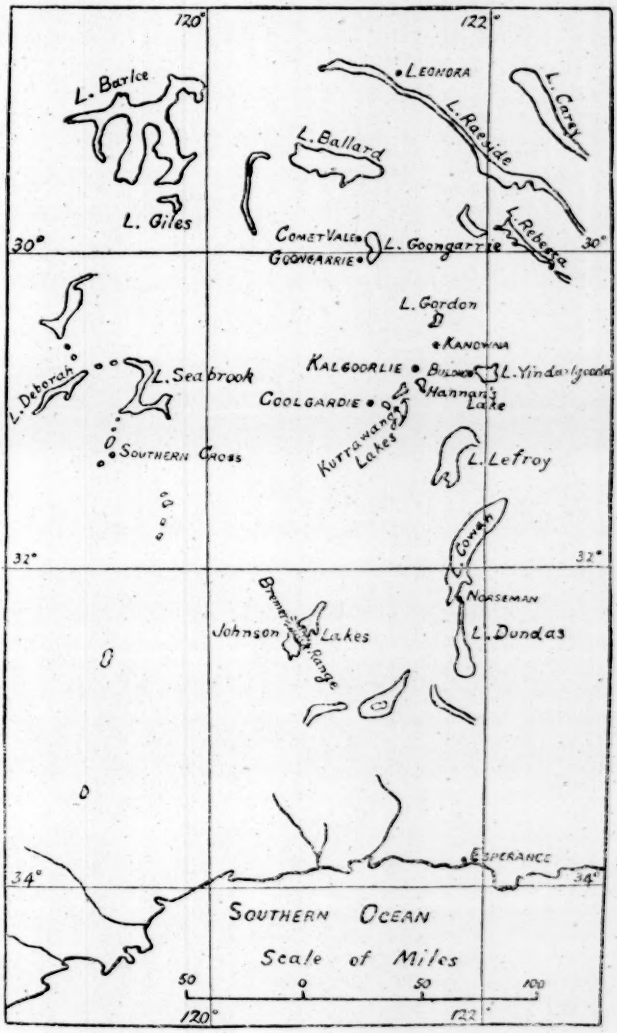
[1] Salts are precipitated on the lake floors on the evaporation of the transient thin sheets of water, but so far as the writer is aware there is no thickness of salt on any of the lakes. The terms "salt lakes" and "salt lake division" are therefore misnomers. "Dry lakes" or "playas" more suitably indicate the character of the lakes, but as the latter are frequently connected with one another by defined or ill-defined channels, and as many undoubtedly lie along the main drainage lines of the country, the writer has suggested the term "stream-lake system" for this dual capacity of portions of the drainage system. The terms "salt lakes" and "dry lakes" have become so firmly rooted in local usage that they will probably remain. It is difficult to suggest a suitable name for the physiographic division instead of "salt lake division". "Dry lake or central division" would perhaps be the least objectionable of any.

[2] As to various theories, see J. W. Gregory, "The Lake System of Westralia," Geog. Journ., June, 1914, pp. 656–64, map. See also C. G. Gibson, Bull. 37, Geol. Surv. W. Austral., 1909, p. 12, and Bull. 42, Geol. Surv. W. Austral., 1912, pp. 11, 12; J. T. Jutson, op. cit., pp. 138–58, and also Geog. Journ., December, 1917, pp. 418–37, map, figures; A. Montgomery, Journ. Roy. Soc. W. Austral., vol. ii, pp. 59–96, map, 1915–16; J. W. Gregory, Geog. Journ., October, 1916, pp. 326–31; and C. S. Honman, Bull. 71, Geol. Surv. W. Austral., 1917, p. 144, and Bull. 73, Geol. Surv. W. Austral., 1917, p. 17.

[3] Geol. Mag., August, 1897, pp. 363–6.

MODE OF OCCURRENCE OF THE ROCK-CLIFFS AND FLOORS, AND ASSOCIATED FEATURES. (Map I.)

The lakes are generally long in proportion to their width, so that when their trend is referred to it is intended to indicate the direction of the lake along its "length". The trend of different lakes may be



MAP I.—Showing the principal "dry" lakes in South-Central Western Australia.

in almost any direction. Many vary from approximately north and south, through north-north-west, north-west, to west-north-west. Some trend north-easterly, and others are approximately east and west. Probably, however, in the main there is an approximation to north and south with variations to the east and to the west of north respectively. When the term "western shore" or "western side" is used in this paper, it is meant to include not only the true western shore when the lake trends approximately north and south, but also the south-western or north-western shore when the lake trends north-west or north-east respectively, because the remarks below as to rock-floors and cliffs apply to the westerly shores as a whole, despite the deflection of the trend of the lakes from north and south.

Along the western shores of many, and along the northern shores of some, of the lakes, rock-cliffs and rock-floors occur. The eastern and southern shores are usually destitute of these features, which are replaced by silt floors, sand dunes, and sand plains.

The cliffs are rocky, generally steep, and frequently form very prominent features in the landscape, when they project as a series of bold headlands into the lake. So far as known, the commonest rocks forming the cliffs are what may be called "greenstones", a field term which includes many kinds of basic igneous rocks, which, however, need not be enumerated here. Cliffs are also formed of "jaspers" (quartz hæmatite schists) and granites. At the base of the cliffs rock floors of similar or associated rocks frequently occur. These floors are of such smoothness that the writer has termed them "billiard-table rock-floors". They may be visible outward from the base of the cliffs only for a chain or two or they may extend for hundreds of yards up to a mile or more. Such floors tend to be covered by the fine silts of the lake, and as these silts vary in thickness and superficial area (although little is yet known as regards their thickness), the extent of the floors exposed also varies.

The rocky cliffs are being worn away by various agents of erosion, the nature of which is described when discussing the meaning of the rock-cliffs and floors.

Some lakes may have no rock-cliffs on any side, but the writer is not aware of any with cliffs on the eastern side. It is possible that such last-mentioned cliffs nevertheless do occur, but if so they must be rare.

Small valleys may enter lakes, and the lower portions of such valleys may, by lateral erosion, become arms of the lakes.

Examples of Lakes with the Features described in South-Central Western Australia. (Map I.)

Kurrawang Lakes, south of the railway line between Kalgoorlie and Coolgardie. According to C. S. Honman's maps and descriptions[1] the lakes are bounded on the west and north by rock-cliffs, and on

[1] Bull. 56, Geol. Surv. W. Austral., 1914, pls. i, ii, fig. 1, pp. 10–12, 34.

the south and east by sand plains and sand dunes. The prevailing wind is stated to be north-westerly.[1]

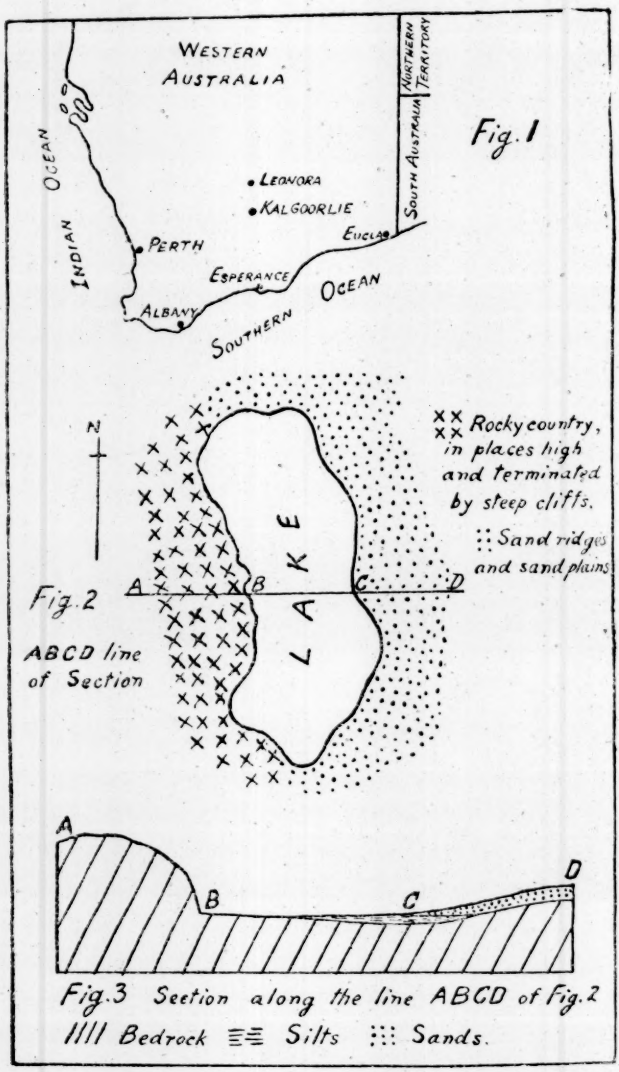
Hannan's Lake, south-east of Kalgoorlie. Honman's maps and descriptions[2] show that rock-cliffs and rock-floors occur on the western shore of the lake, and sand dunes and sand plains on the southern and south-eastern shores, the material forming the dunes and plains being blown from the north-west. Honman also refers (p. 36) to the migration of the lake to the north-west owing to this removal of material.

Lakes Carey, Raeside, Rebecca, and Goongarrie.—These lakes form a remarkable group. They all lie to the east of the railway line running north from Kalgoorlie to Leonora, Lake Carey being the most easterly and Lake Goongarrie the most westerly. Lakes Carey, Raeside, and Rebecca have been mapped and described by Honman, who states[3] that they all run north-west and south-east; that all have escarpments and rock-floors on the western sides and sand dunes on the eastern; that the rock flooring on the western side is probably due to migration; and that the fact that the rock-flooring is on the western side in the case of every lake in the district is probably due to the prevailing direction of the wind being from the south-west.[4] The writer can confirm from personal observation the occurrence of rock-cliffs and floors on the western side of Lake Raeside and their absence, in the areas seen by him, on the eastern. The writer's observations in regard to Lake Goongarrie, which trends north and south, show that rock-cliffs and rock-floors occur on the western side, and sand plains and sand dunes on the eastern. The dominant winds appear to be westerly. Another moderately large lake, west of Lake Goongarrie and of the railway line, has not been examined by the writer.

Lakes north of Southern Cross.—T. Blatchford[5] points out that wind-blown deposits occur on the southern or south-eastern edges of the lakes, the northern and western shores being usually more or less precipitous with bare rock-floors or covered with very thin deposits. He concludes that the lakes are migrating westward, and from his remarks the prevailing winds are probably north-westerly.

The Johnson Lakes, Bremer Range. Honman[6] in referring to these lakes states that on the north-western side are found hard rock outcrops and cliffs, and on the south-eastern blown sand and gypsum, forming wide sandy slopes and dunes, due to wind action.

[1] Op. cit., p. 11, fig. 1.
[2] Bull. 66, Geol. Surv. W. Austral., 1916, pl. i, pp. 11, 36.
[3] Bull. 73, Geol. Surv. W. Austral., 1917, pp. 17–19.
[4] It might here be noted that Honman accepts J. W. Gregory's theory on the lakes as a whole as dismembered river systems. See Bull. 71, 1917, p. 144, and Bull. 73, 1917, p. 17, Geol. Surv. W. Australia. He also notes (Bull. 71, p. 15) that Lakes Carey, Raeside, and Rebecca cross the strike of the rocks, and suggests that these lakes may belong to a different cycle of erosion uninfluenced by geological structure. On the ancient river theory, it could be contended in explanation of this feature that the old streams were superposed. The question cannot be discussed here. It will be dealt with elsewhere.
[5] Bull. 71, Geol. Surv. W. Austral., 1917, pp. 23, 24.
[6] Bull. 59, Geol. Surv. W. Austral., 1914, p. 195.



MAP II.—Fig. 1: Locality map of the southern portion of Western Australia. Fig. 2: Generalized plan of a "dry" lake with rock-cliffs and rock-floor. Fig. 3: Diagrammatic section across a "dry" lake from west to east, showing (A) the rock-cliffs and rock-floor (B) on the western side, fine silts (C) towards the eastern side, and blown sands (D) encroaching on the eastern margin of the lake.

Lake Cowan, Norseman. W. D. Campbell's maps and descriptions[1] of this lake clearly show that rock-cliffs exist on the western shore and blown sands on the eastern.

Lake Barlee.—H. W. B. Talbot's maps[2] show this lake to be star-shaped; but where north and south trending portions of the lake abut rock ridges, the latter are on the western shore of the lake.

Lake Gordon, near Kanowna. This lake has rocky cliffs on the western shore and sands on the eastern, as personally observed by the writer.

Meaning of the Phenomena described.

The facts stated above appear to decisively indicate that the occurrence of rock-cliffs and rock-floors on the western sides of "dry" lakes, and their absence on the eastern sides (with replacement on such eastern sides by sand and silt), are not merely coincidences. There must be some agent now or formerly operating with dominant power over wide areas in order to produce such remarkable uniformity of conditions. Such power seems to be restricted either to marine erosion, or to erosion by terrestrial waters, or to wind erosion. These possibilities are now considered.

Marine erosion does not seem to apply, for reasons that will be briefly stated. (1) No evidence has been adduced that the country has been recently submerged beneath the ocean farther north than Norseman,[3] which is about 120 miles north from the southern coast of Australia. This distance, however, is short in comparison with the north and south length of the belt occupied by the "dry" lakes. (2) The marine theory claims that the forms of the cliffs are due to marine erosion. It therefore assumes that these cliffs have practically sustained no erosion since their supposed emergence from the sea; an assumption the validity of which is at once questioned owing to the fact that normal subaerial erosion—apparently to a considerable extent—has taken place near the coast since the last undoubted emergence from the sea of the coastal lands, and consequently subaerial erosion farther inland must have also occurred. (3) The effect of present erosional processes is ignored. (4) As there are long sub-parallel lines of cliffs forming the western shores of lakes, such cliffs, on the theory of marine erosion, could only be produced by many distinct uplifts, with pauses long enough to allow the lines of cliffs to be successfully eroded. This means that the country should rise by a series of marine-cut very wide benches one above another, a state that, so far as all knowledge of the country goes, does not exist. Moreover, as the cliffs face the east, the emergence, on such theory, must have been from west to east, that is, away from the present western coastline, the last land to emerge being

[1] Bull. 21, Geol. Surv. W. Austral., 1906, p. 21, and plate.

[2] Bull. 45, Geol. Surv. W. Austral., 1912, pls. i, ii.

[3] Well to the east of Norseman the sea in probably Miocene times was much farther north, but this formerly sea-covered land is outside the area discussed in this paper.

towards the South Australian border. Again, no evidence of this has been adduced.

Erosion by terrestrial waters, either by river or lake, seems also inadequate to explain the facts. Fluviatile action cannot be conceived to produce such forms in their present positions. Former deep permanent lakes could produce cliffs, but such cliffs would not be restricted to practically one side only, nor, stating the matter in another way, would the high belts of country be bounded by lakes, and the rock-cliffs of such lakes, on mostly one side only. Furthermore, there is at present no evidence available that such deep permanent lakes ever existed. Lacustrine deposits, with abundant fossils, should occur, but so far they have not been discovered, apart from the leaves in a deep alluvial deposit at Coolgardie. Rock benches are characteristic marks of former deep permanent lakes, but none has ever been found.[1] With regard to the action of the present lake waters, as they remain for such a short period and, so far as observed by the writer, are only a few inches deep at the margin, abrasion by such waters seem out of the question, although there is probably some removal of fine detritus from the base of the cliffs by the lapping of the transient waters. Moreover, the objection as to abrasion on practically one side only, also applies to the present lake waters.

There remains, then, but wind erosion, and this most satisfactorily explains the facts as at present known. It is not claimed that wind erosion alone is competent to produce the cliffs and rock-floors, and to cause the lakes to migrate. The subaerial agents of erosion, comprising insolation, "exsudation," the beating action of rain, and general atmospheric weathering, are wearing down the cliffs and rock-floors, and the gentle lapping of the lake waters may remove some of the detritus. The wind, however, seems to be the dominating agent, partly by corrasion, but chiefly by deflation. The debris is swept away from the cliffs, thus allowing their further destruction, and the billiard-table floors are produced. Sand is carried around or across the lake by the wind and deposited on the eastern and other sides. This, aided by the deposition of fine silt on the lake floor, forces the water westward, thus assisting to bring about its migration. In the course of such migration higher rock belts are met, cliffs formed, and then gradually worn back. Hence rock-cliffs and rock-floors occur on the western sides, and sands on the eastern.

If migration has occurred to any extent, and if such migration is chiefly due to wind erosion, then, without regard to other considerations, the lakes are undoubtedly, in part at least, deflation lakes.

[1] It is not contended that larger lakes never existed. They have possibly done so, but there is no available evidence that they formed deep permanent lakes. What evidence there is points, in some instances, to wider areas of shallow ephemeral lakes or playas practically similar to those now in existence, and to the probability that such greater lakes have, owing to local conditions, shrunk. In other instances the migration of a lake may account for an apparently greater former lake of the playa type.

This conclusion thus bears out, to some extent at least, Woodward's original idea that such lakes are due to wind action.

In their general trend, the lakes lie along drainage lines—more or less dismembered and probably in part deformed—which have been formed under existing conditions or have belonged to an old river system when the climate was moister and perhaps the country lower than at present, as suggested by Gibson and J. W. Gregory. That they are the remains of an ancient river system formed under different climatic conditions than those of to-day has not yet been demonstrated; but if it were, such demonstration would not, in the writer's opinion, invalidate the conclusion that portions at least of the lakes and the striking characteristics, the subject of this paper, are dominantly due to wind erosion.

Few observations have as yet been recorded as to the dominant direction of the wind, but from the writer's personal, although limited, observations in the Comet Vale–Goongarrie district, made since writing his physiography of Western Australia, and the paper referred to above in the *Geographical Journal*, it may be said that although there is perhaps no *prevailing* wind, yet the *dominant* wind appears to be from the west (north-west, west, or south-west). As shown above, Honman and Blatchford also hold that the dominant wind is from the same quarter.

Woodward[1] has noted the retarding effect of the ground-water table on wind erosion on lake-floors, and this feature may help to explain the very even surfaces of the billiard-table rock-floors, the wind receiving at least a temporary check on reaching the more or less saturated zone. Honman[2] also believes that during lake migration the rock-floor is kept level by moisture. The silts of the lakes are always moist, except perhaps, at times, the actual surface film. A moist surface, in addition to preventing the removal of material, may also, as pointed out by A. W. Grabau, with regard to the American playas,[3] catch dust particles carried across the surface by the winds, and by this means the thickness of the deposits may be increased. Hence the silts of the eastern portions of the "dry" lakes may be partly wind-blown, and not entirely due to deposition under water, this wind-blown material being probably derived from the western areas.[4] If such wind transportation does take place it shows that, despite its retarding effect, the hygroscopic character of the silt is not an absolute bar to wind transportation, probably because the actual surface may (at various times at least) be sufficiently dry to allow such transportation. In any event, however, from the facts set out in this paper, it seems clear that the wind can and does remove material from the western sides of the "dry" lakes.

[1] Op. cit., p. 365.
[2] Bull. 66, Geol. Surv. W. Austral., 1916, p. 36.
[3] *Principles of Stratigraphy*, New York, 1913, p. 603.
[4] Dust is no doubt also caught by the lake waters when they are in existence, and this is then deposited as an aqueous sediment.

V.—Notes on the genus *Homalonotus*.

By F. R. Cowper Reed, Sc.D., F.G.S.

(*Concluded from the June Number, p. 276.*)

6. *Burmeisteria*, Salter, 1865.

THE type of this section is the Lower Devonian species *Homalonotus Herscheli* (Murchison)[1] from South Africa and the Falkland Isles.[2] The characters of the section were stated by Salter to be as follows: "Elongate, convex; head triangular, eyes approximate on gibbous cheeks. Glabella distinct, lobeless, spinous. Thorax slightly lobed and spinous, as is also the many-ribbed pointed tail." It should at once be stated that the type-species has neither a lobeless nor a spinous glabella, and Salter apparently added in these characters from the Rhenish *H. armatus*, Burm., which he included in the section. The only British form quoted by Salter is one from Devonshire based on a pygidium which does not conform to the above definition and was described under the name *H. elongatus*.[3] Woodward,[4] in reviewing the Devonian species of *Homalonotus*, follows Salter in including the latter species in *Burmeisteria*.

The course of the facial sutures in *H. Herscheli* is important; they bend in rather suddenly in front, so as to form a transverse, gently arched or sinuated commissure and meet in the middle at a very obtuse angle. The pre-glabellar area is large, but the pre-sutural area is very narrow, as in *H. Knighti*. The parallel epistomal sutures arise nearly at right angles to the transverse commissure, and cross over the margin to the inferior surface. The epistome itself has a median apiculus projecting in front of the margin of the head-shield, which is otherwise subtruncate. Lake's species *H. colossus*,[5] also from the Bokkeveld Beds of South Africa, is represented as possessing a similar epistomal projection, and in the Brazilian species *H. noticus*, Clarke,[6] it is also developed.

It can hardly be doubted that Salter included more than one species of *Homalonotus* under the one specific name *H. Herscheli*, though Clarke (op. cit.) seems inclined to question it. Lake (op. cit.) and Schwarz[7] have established several new closely allied species from the same South African beds, and an examination of Salter's original types, now in the British Museum, has convinced me that *H. Herscheli* admits of division. The typical form is shown by the head-shield (No. 11276) illustrated in his figure 1*a*, *b*, *c*; this specimen comes from the locality Leo Hoek and has a transverse shape, a distinctly lobed glabella, and no coarse tubercles or spines on the surface, except two or three small ones on the pleuro-occipital ring, the general surface of the head-shield being merely ornamented with almost equidistant, widely spaced, coarse granules. The facial

[1] Salter, Trans. Geol. Soc., ser. II, vol. vii, p. 215, pl. xxiv, figs. 1–7, 1856.
[2] Clarke, *Foss. Dev. Parana*, 1913, p. 93, pl. iii, figs. 1–4.
[3] Salter, *Mon. Brit. Trilob.*, p. 122, pl. x, figs. 1–2.
[4] Woodward, Geol. Mag., Dec. IV, Vol. X, p. 29, 1903.
[5] Lake, Ann. S. African Mus., vol. iv, pt. iv, p. 216, pl. xxvi, fig. 1, 1904.
[6] Clarke, op. cit., p. 89, pl. i; pl. ii, figs. 1–13.
[7] Schwarz, Rec. Albany Mus. S. Africa, vol. i, No. vi, pp. 382–91, 1906.

sutures cut the lateral borders in front of the genal angles; the paraglabellar areas are sunken and circumscribed. The pygidium having the same ornamentation is No. 11282, figs. 7*a–d*, from the same locality; this has an interrupted median row of tubercles on the axial rings, with a lateral row of rather larger ones on each side; there are only about half a dozen small tubercles, rather irregularly disposed, on the lateral lobes. The head-shield represented in Salter's figure 2 (No. 11277) has the shape of Schwarz's *H. hippocampus*,[1] but is rather poorly preserved on the upper surface; it is certainly more elongated and triangular than No. 11276, though from the same locality. The large head-shield (No. 11278) from Warm Bokkeveld outlined by Salter in his fig. 3 is crushed and imperfect, but the presence of a distinct large tubercle on each side of the glabella on the faint basal lobes is sufficient to separate it. Perhaps it belongs to Lake's *H. quernus*.[2]

With regard to Salter's figured specimens, illustrated by his figures 4, 5, 6, 8, we can merely say here that none of them agree with the types of *H. Herscheli* in ornamentation or characters, but they suggest a comparison with Schwarz's species *H. horridus*[3] and *H. agrestis*.[4]

Salter included the European Devonian species *H. armatus*, Burm.,[5] in his section *Burmeisteria*, but the anterior end of the head-shield has never been fully described or figured, and so far as we know the truncate edge of the middle-shield corresponds with the almost straight course of the transverse commissure of the facial sutures. In the allied *H. rhenanus*, Koch,[6] the anterior edge is slightly concave and the lateral angles project in front, so that Gürich has chosen the name *Digonus* for this group (see below).

The thorax in all the South African forms ascribed to *H. Herscheli* is obscurely trilobed, and the axis is very wide. The pygidium is always triangular and produced behind into a point; the segmentation is more or less distinct and the joints are numerous. The presence of spines on various parts of the body cannot be regarded as of primary importance, in spite of Salter's opinion, and in the type-specimens of *H. Herscheli* they are either inconspicuous or absent.

Apparently it was mainly because of the presence of spines that Salter included the species *H. elongatus*, Salt., and *H. pradoanus*, De Vern.,[7] in his list of members of *Burmeisteria*. But in both of these the pygidium is rounded behind and not acuminate. The first species, *H. elongatus*, belongs to the same group as *H. Champernownei*, Woodw.,[8] from Devonshire, and a new species, *H. bifurcatus*, Reed MS., from the same locality, of which the description awaits

[1] Schwarz, op. cit., p. 388, pl. ix, figs. 5*a*, *b*.
[2] Lake, op. cit., p. 216, pl. xxvii, fig. 1.
[3] Schwarz, op. cit., p. 385, pl. ix, figs. 1*a–c*.
[4] Ibid., p. 386, pl. ix, figs. 2*a*, *b*.
[5] Koch, op. cit., p. 12, pl. i, figs. 1–6.
[6] Ibid., p. 32, pl. iii, figs. 1–6.
[7] De Verneuil, Bull. Soc. Géol. France, ser. II, vol. vii, p. 168, pl. iii, figs. 4*a*, *b*, 1850.
[8] Woodward, GEOL. MAG., Dec. II, Vol. VIII, p. 489, Pl. XIII, 1881.

publication, must also be ascribed to it. The well-marked trilobation of the body, the narrow and distinctly defined axis, and certain features of the head-shield (see below under *Burmeisterella*), as well as the oval or semicircular pygidium, mark off this group from the true *H. Herscheli*. The pointed pygidium referred by Woodward [1] to *H. Champernownei* on a subsequent occasion seems to belong to Gürich's group *Digonus* and is certainly in no way related to *H. elongatus*.

With *H. pradoanus* we must associate *H. Gervillei*, De Vern.,[2] and *H. Barratti*, Woodw.,[3] the latter from Cornwall. The pygidium has a rounded semi-oval shape, a more or less distinct border, but no acuminate extremity. The axis in both the thorax and pygidium is only faintly marked. The head-shield as seen in *H. Gervillei*, which is the best-known member of the group, has distinctive features (see below under *Parahomalonotus*). The surface is ornamented with coarse granules and tubercles, but not spines. *H. Gervillei* was first described from the Devonian of the Bosphorus, but was more fully described and figured by Bayle (op. cit.) from the Calcaire de Néhou, Manche, France. Another allied French species, *H. Hausmanni*, Rouault,[4] must be included in this group of species.

Thus, in addition to the *H. Herscheli* group (which is the true type of *Burmeisteria*), we find three other groups, i.e. (1) the *H. rhenanus* (= *Digonus*, Gürich) group, and also the more distinctly marked groups of (2) *H. elongatus* and (3) of *H. Gervillei*, all developed in Devonian times and sometimes all included by palæontologists in *Burmeisteria*.

7. *Calymenella*, Bergeron, 1890.

Bergeron [5] established this genus in 1890 with a new species, *C. Boisseli*, Bergeron, from the Ordovician of Hérault, as its type, and he also included in it the species *Calymene Bayani*, De Trom. et Lebesc.[6] The characteristics of the genus were given as follows: "Glabelle peu bombée, arrondie en avant, portant trois sillons, dont les deux derniers sont bien visibles; le postérieur s'infléchit en arriére. Lobes peu accusés. Joues fixes larges. Limbe très développé en avant de la glabelle et pouvant se terminer en pointe. Pygidium de Calymene." The facial sutures are believed to cut the lateral margin behind, but it is not clear if they unite in front on the upper surface of the head at the base of the rostrum. It seems, however, that such may possibly have been the case, judging from some of Bergeron's figures, and this would explain the absence of the rostrum from some of the specimens of the middle shield. The free cheeks are unknown.

As Pompecki [7] has remarked, we may probably regard *Calymenella*

[1] Ibid., Vol. IX, p. 157, Pl. IV, Fig. 3, 1882.

[2] Bayle, Explic. Carte Géol. France, iv, pl. ii, figs. 1, 3, 6, 1878.

[3] Woodward, GEOL. MAG., Dec. IV, Vol. X, p. 28, woodcut, 1903.

[4] Rouault, Bull. Soc. Géol. France, ser. II, vol. viii, p. 379, woodcut, 1851.

[5] Bergeron, Bull. Soc. Géol. France, ser. III, vol. xviii, p. 365, pl. v, figs. 1–7, 1890.

[6] De Tromelin & Lebesconte, Bull. Soc. Géol. France, ser. III, vol. iv, p. 599, 1875; Bergeron, op. cit., pl. v, figs. 8–13.

[7] Pompecki, Neues Jahrb. f. Min. Geol., Bd. i, p. 241, 1898.

as a subgenus of *Homalonotus*, but it is at any rate an early and aberrant form. Apart from the presence of the rostrum, it seems allied to the Grès de May species of this genus, rather than to any species of *Calymene*. A rostrum is developed in more than one genus, and *Ampyx* and *Probolium* are instances. Vogdes[1] would apparently refer his species *Calymene rostrata*, from the Clinton Formation, to this group or genus *Calymenella*, but it has a typically lobed glabella like *Calymene*, and the facial sutures cut the anterior margin on each side of the base of the rostrum, which is a triangular projection of the border, and therefore is structurally distinct.

8. *Digonus*, Gürich, 1909.

The type-species chosen by Gürich is *H. gigas*, Roemer,[2] and Gürich's[3] definition of the subgenus may be rendered as follows: Middle-shield truncate or concave anteriorly, so that the front margin is biangulated; glabella subquadrate; pygidium with pointed extremity. The section is characteristic of the Lower Devonian, and includes a large number of Continental species, of which Gürich mentions *H. scabrosus*, Koch,[4] and *H. rhenanus*, Koch.[5] We may add to Gürich's definition the fact of the distinct segmentation of the pygidium, which separates these European Lower Devonian species from *Dipleura*, as Kayser pointed out in a footnote to Koch's memoir (op. cit., p. 10). Perhaps the British species *H. goniopygæus*, Woodw.,[6] belongs to this group, as the pygidium, which alone is known, agrees with Gürich's type in general characters.

The truncate straight or concave anterior end of the middle-shield in the type-forms corresponds to the course of the transverse commissure of the facial sutures, and the peculiar course of this commissure seems to mark off this group of species from the *H. Herscheli* group, which they resemble as far as the pygidium is concerned. In none of them is the true anterior margin of the head-shield known, so that we are ignorant if the epistome projects in front or if there is a wide pre-sutural area. For these reasons they may be regarded as distinct from the typical *Burmeisteria* group, and they seem worthy of complete separation from it.

9. *Schizopyge*, Clarke, 1913.

Clarke[7] suggested this name for the aberrant species *H. longicaudatus*, d'Archiac, Fischer, and de Verneuil,[8] of the Lower Devonian of Constantinople, and the two Brazilian species,

[1] Vogdes, Amer. Journ. Sci., ser. III, vol. xxiii, p. 475, 1879; id., Proc. Acad. Nat. Sci. Philad., 1880, p. 176, figs. 1, 2; id., Bibliogr. Palæoz. Crust. (Occas. Papers Calif. Acad. Sci., iv, 1893, p. 223).

[2] Roemer, Verstein. Harzgeb., t. xi, p. 39, fig. 10, 1843.

[3] Gürich, Leitfossilien, Lief. ii, Devon, pp. 156, 157, fig. 42, 1909.

[4] Koch, op. cit., p. 115, pl. iii, figs. 8–10; pl. iv.

[5] Koch, op. cit., p. 32, pl. iii, figs. 1–6.

[6] Woodward, GEOL. MAG., Dec. II, Vol. IX, p. 157, Pl. IV, Fig. 1, 1882.

[7] Clarke, *Foss. Dev. Parana*, 1913, pp. 97–101.

[8] Tchichatcheff, Asie Mineure, pt. iv, Paléont., 1866, p. 2, pl. i, fig. 8 (figure not published).

H. acanthurus, Clarke,[1] and *H. parana*, Clarke,[2] also from the Lower Devonian. The characteristic feature of these forms, of which only the pygidium and some doubtful fragments of the thorax are known, is that the pleuræ project over the margin of the pygidium as short broad lappets in direct continuation and not as separate spines as in *Cryphæus*. This character is, however, so unlike that of other groups of *Homalonotus* that the reference of these species to this genus seems extremely doubtful. No figure of the species *H. longicaudatus* was given in the original work referred to, but Clarke[3] figures a specimen from the Bosphorus under this name.

Doubtful Members of *Homalonotus*.

Of species doubtfully referred to the genus *Homalonotus* we may mention *H.* ?*punctillosus*, Törnquist,[4] from the Leptæna Limestone of Sweden, which has been recorded from the Keisley Limestone[5] in England. This trilobite, by the course of the facial sutures, seems undoubtedly to belong to another genus.

There is also one described and figured by McCoy from the Kildare Limestone, Ireland, as *H. ophiocephalus*,[6] which seems to be a hypostome of some other genus, but I have only seen the figured example, and it is somewhat poor and problematical.

The species *Asaphus brevicaudatus* (Desl.),[7] which Bigot[8] has removed to Corda's genus *Plesiacomia*,[9] may apparently be regarded as of independent generic rank, judging from the published descriptions and figures; but I have not been able to examine any specimens of it.

Position and Affinities of *Homalonotus*.

There has been considerable diversity of opinion with regard to the position of *Homalonotus* sens. extenso in any general scheme of classification of the Trilobita. The genus has usually been put in the family Calymenidæ, and Pompecki[10] has pointed out its close connexion with the genus *Calymene* and their probable common descent from Hicks'[11] genus *Neseuretus*, and he was so much impressed with the evidence of their close affinity as to bring together under one new generic name *Synhomalonotus* the combined groups of those species of *Calymene* which are comprised in the *C. Tristani*, *C. Arago*, and *Plychometopus* Series. But he recognized the existence

[1] Clarke, "Trilob. Grez de Erere e Maecuru, Brazil": Arch. Mus. Nac. Rio de Janeiro, vol. ix, p. 10, pl. i, figs. 9, 10, 1890.
[2] Clarke, *Foss. Dev. Parana*, p. 97, pl. iii, figs. 5, 6.
[3] Clarke, "Trilob. Grez de Erere e Maecuru, Brazil," p. 14, pl. i, fig. 8.
[4] Törnquist, Undersokn. Siljans. Trilobitf., t. i, p. 44, figs. 46, 57; t. ii, figs. 1, 2.
[5] Reed, Quart. Journ. Geol. Soc., vol. lii, p. 411, 1896.
[6] McCoy, *Syn. Silur. Foss. Irel.*, 1846, p. 53, pl. iv, fig. 4.
[7] Deslongchamps, Mém. Soc. Linn. Calv., ii, pl. ii, figs. 3, 4, 1825.
[8] Bigot, Bull. Soc. Géol. France, xvi, p. 433, pl. v, fig. 1c, 1888.
[9] Corda, *Prodrome*, 1847, p. 55, pl. iii, fig. 30.
[10] Pompecki, Neues Jahrb. f. Miner. Geol., Bd. i, pp. 187–243, 1898.
[11] Hicks, Quart. Journ. Geol. Soc., vol. xxix, pp. 44, 45, 1873.

of two families, the Calymenidæ and the Homalonotidæ, and Gürich [1] in 1908 adopted this classification. Swinnerton [2] in 1915 followed Gürich, but put the two families in a section *Calymmenina* of a sub-order Conocoryphida, which he ascribed to Beecher's group *Opisthoparia* because of their supposed derivation from the Olenidæ.

The family Calymenidæ (in its wide sense, including *Homalonotus*) was put by Beecher in 1900 and by Raymond in 1913 in the group *Proparia* on account of the course of the facial sutures. But Gürich (op. cit.), finding a difficulty in placing it in either of these groups, instituted a new group, which he called *Gonatoparia*, for those genera in which the facial sutures cut the genal angles, and he placed the Calymenidæ and Homalonotidæ in it. Koch, however, had seen that some of the Devonian species had the point of section in front of the genal angles, and it is not improbable that some of those from the Grès de May possessed the same character. If, therefore, we are of opinion that Beecher's scheme and principles of classification of the Trilobita are natural and generally applicable, it seems as if *Homalonotus* should be associated with the *Proparia* rather than with the *Opisthoparia*. The idea of the derivation of *Homalonotus* from the Olenidæ, and therefore of its place in the *Opisthoparia*, has arisen from its supposed relation to Hicks' unfortunate genus *Neseuretus*, which Pompecki referred to the Olenidæ, having failed to see that it was of a composite character. So much confusion and misunderstanding appears to have arisen about the genus *Neseuretus* that a few remarks upon it may here be made. The type-specimens (all of which are poor) are mostly in the Sedgwick Museum and have been studied by myself. The first-described species, *N. ramseyensis*, Hicks,[3] is apparently identical with *Calymene Tristani*, Brongn., which was chosen by Pompecki as the type of his genus *Synhomalonotus*. The second described species, *N. quadratus*, Hicks,[4] is an indisputable *Homalonotus* belonging to Salter's group *Brongniartia*. The third species, *N. recurvatus*,[5] is probably referable to *Calymene* and seems to resemble *H. Heberti*, Barrois,[6] from the Grès armoricain. The fourth species, *N.? elongatus*, Hicks,[7] may also belong to *Calymene*, but the type is in a poor state of preservation, so that the characters are difficult to distinguish. It is now ascertained that the beds from which these specimens came are of Arenig and not Tremadoc age. From the above remarks it appears that *Neseuretus* must be regarded as a composite and heterogeneous assemblage of species and it has no right to be retained as a separate generic designation.

Apart from all other distinctions the fundamental difference between *Homalonotus* and *Calymene* seems to be that in the former

[1] Gürich, Leitfossilien, Lief. i, Camb. Silur., 1908, p. 70.
[2] Swinnerton, GEOL. MAG., Dec. VI, Vol. II, pp. 494, 540–3, 1915.
[3] Hicks, op. cit., p. 44, pl. iii, figs. 7–10, 16–22.
[4] Ibid., p. 45, pl. iii, figs. 11–13, 23–6.
[5] Ibid., p. 45, pl. iii, figs. 5, 6.
[6] Barrois, Bull. Soc. Géol. France, ser. III, vol. xiv, p. 802, pl. xxxvi, fig. 14, 1886.
[7] Hicks, op. cit., p. 45, pl. iii, figs. 1–3.

the facial sutures unite in front on the upper surface of the head-shield, although frequently very close to the margin, whereas in *Calymene* they cut the anterior edge of the head-shield at some distance apart and are connected together on the lower surface. In *Homalonotus*, therefore, the median portion of the front margin of the head-shield is formed by the epistome, sometimes expanded and recurved so as to form a broad pre-sutural prora, whereas in *Calymene* the same part of the head-shield is composed of the pre-glabellar post-sutural area, and the epistome is wholly confined to the lower surface of the head-shield, not appearing at all on the upper surface. The obsolescence, more or less complete, of the glabellar lobes and the frequent loss of trilobation in the thorax and pygidium of *Homalonotus* are secondary characters of degeneracy, and can hardly be regarded of primary morphological importance in comparing the two genera. The correspondence in the number of segments in the thorax should not have too much stress laid upon it, for in the fairly homogeneous genus of *Illænus*, which shows modifications in many respects parallel to *Homalonotus*, the number of segments varies from eight to ten.

The earlier species of *Homalonotus*, such as those from the Grès de May, show a remarkable resemblance in the characters of the pygidium to *Calymene*, and in some species (e.g. *H. biserratus*) even the bifurcation of the tips of the pleuræ near the margin is indicated. We must, however, remember that even in these early representatives of *Homalonotus* all the special characters of the head-shield and glabella are fully developed. The more distinct trilobation of the body and pygidium is an additional feature in these Grès de May species, and they undoubtedly come nearest to *Calymene*.

It is worthy of remark that the genus *Calymene* itself did not tend to differentiate into subgenera, its general character remaining extraordinarily constant during its whole stratigraphical range, whereas *Homalonotus* is not nearly so homogeneous an assemblage of species, considerable variation having taken place along more or less distinct lines of development.

We may note a somewhat remarkable parallelism in the generic life-history of *Homalonotus* sens. ext. and *Asaphus* sens. ext., though in the latter case the development took place more rapidly and simultaneously, being practically within the confines of the Ordovician, but in more or less distinct biogeographical areas. A rounded semicircular or transverse head-shield goes with a rounded semicircular or transverse pygidium with an entire margin. A pointed and elongated head-shield accompanies a pointed and elongated pygidium, and the number of segments in the latter similarly increases. A somewhat parallel case exists in the genera *Phacops* and *Dalmanites*.

In *Asaphus* we may also remark that the facial sutures, which, as in *Homalonotus*, unite on the upper surface, may form a regular curve or meet in a pointed arch or ogive; they may also lie close to the margin or well inside it, or may even cut the front edge and be connected below it. But there is no pair of epistomal sutures in *Asaphus*, and the facial sutures cut the hind margin of the

head-shield well within the genal angles; so that there can be no question of direct genetic affinities, but only of homœomorphic development.

Classification.

The species of *Homalonotus* may be grouped together into several sections or subgenera on the strength of the character and course of the facial sutures, the development of the epistome and doublure, the degree of trilobation of the thorax, and the shape, trilobation, and segmentation of the pygidium. These characters are variously combined, but on the whole two large divisions may be recognized so far as pygidial characters alone are concerned, one of which is marked by rounded and the other by pointed pygidia. In the earliest members of the genus the pygidia are short, rounded, and composed of few segments, and the trilobation is well marked; in some of the Devonian species the rounded form again prevails, but there is a larger number of segments, and the trilobation is more or less lost. In the Silurian and most of the Devonian species the pointed elongated pygidium, composed of many segments, with or without distinct trilobation, is found conspicuously developed.

Many of the groups or sections have already received names from various authors, but some of these groups are not homogeneous and require subdivision, as the foregoing remarks have indicated. Whether these groups are of subgeneric or only lesser rank may be a matter of opinion; but in the following list the groups appear to possess combinations of characters of morphological importance, and it will be observed that the groups also have a stratigraphical relation or limitation, and therefore suggest phylogenetic significance. We may therefore maintain that they are not artificial assemblages of species, but correspond to certain natural divisions of the genus. In some cases it is unfortunate that the species are only imperfectly known, or that specific names have been attached to mere fragments of individuals, or that disconnected portions of doubtful association have been brought together under the same specific designation. But these are minor defects which are unavoidable, and subsequent work may remedy them.

Subgenera.

1. *Eohomalonotus*, nom. prop. (= *Brongniartia* (pars), Salter, *non* Leach, *nec* Eaton).

Head-shield transverse, rounded, more or less semicircular. Facial sutures uniting close to anterior margin or on margin in regular wide curve, and posteriorly cutting lateral margins slightly in front of genal angles. Pre-glabellar area wide; pre-sutural band very narrow or wanting. Thorax with well-marked trilobation; axis not wider than pleural portions. Pygidium short, broad, expanded, composed of few segments (six to eight); axis distinct; pleuræ continued to edge or nearly to it; doublure vertical or steeply inclined at sides, simple, of nearly uniform width all round or narrowing slightly posteriorly.

TYPE.—*Homalonotus Brongniarti* (Desl.).
RANGE.—Lower Ordovician.
DISTRIBUTION.—N. France, Cornwall, Shropshire, Bohemia?

EXAMPLES.

H. Deslongchampsi, de Trom.
H. Bonissenti, Mor.
H. serratus, de Trom.
H. Vicaryi, Salt.
H. besnevillensis, Bigot.
H. incertus, Bigot.
H. Morierei, Bigot.
H. Barroisi, de Trom.
H. biserratus, sp. nov.
H. quadratus (Hicks).
? *H. bohemicus*, Barr.
? *H. draboviensis*, Novak.[1]
? *H. medius*, Barr.

REMARKS.—This section comprises the earliest representatives of the genus *Homalonotus*. There is a close connexion between it and Pompecki's *Synhomalonotus*, through which the genus is related to *Calymene*.

2. *Calymenella*, Bergeron.

Head-shield triangular, produced in front into a rostrum. Facial sutures uniting in front in regular continuous curve at base of rostrum and inside margin. Pygidium semicircular, transverse, composed of few segments, distinctly trilobed; axis and pleuræ well marked.

TYPE.—*H.* (*Calymenella*) *Boisseli* (Bergeron).
RANGE.—Ordovician.
DISTRIBUTION.—France.
EXAMPLE.—*H.* (*C.*) *Bayani* (De Trom. & Lebesc.).

REMARKS.—The peculiar distinguishing feature of this subgenus is the possession of the rostrum, the precise nature of which has not been thoroughly investigated; but it seems to be merely a much elongated narrow prora, as in *Dipleura*, and to be wholly pre-sutural in origin and perhaps epistomal in nature. The head-shield and glabella in other respects seem to resemble *Eohomalonotus*, and the pygidium is unmistakably of the same type. Bergeron regarded the two species mentioned above as constituting a distinct genus, but Pompecki considered that it was only a subgenus of *Homalonotus*.

3. *Brongniartella*, nom. prop. (= *Brongniartia* (pars), Salter, section 1, *non* Leach, *nec* Eaton).

Head-shield rounded, semi-elliptical or semicircular, wider than long. Facial sutures uniting close to anterior margin or on margin in regular wide curve, and posteriorly cutting lateral margins nearly at genal angles. Glabella urceolate, rhomboidal, or subconical, generally lobeless. Pre-glabellar area of moderate width; pre-sutural band very narrow or wanting. Thorax with trilobation more or less indistinct; axis wider than pleural portions. Pygidium rounded, semi-oval or parabolic, composed of nine to twelve segments; axis distinct; pleuræ continued nearly to margin; border usually developed but not defined; doublure flat, horizontal, closely infolded, of nearly uniform width.

TYPE.—*H. bisulcatus*, Salter.
RANGE.—Middle and Upper Ordovician.
DISTRIBUTION.—England.

[1] Novak, "Zur Kennt. böhm. Trilob.": Beitr. Palæont. Öst. Ungarns, p. 27, pl. viii, figs. 9*a-c*, 1884.

EXAMPLES.

H. Sedgwicki, Salter.
H. Edgelli, Salter.
H. Tawneyi, sp. nov.
H. ascriptus, Reed.
? *H. rudis*, Salter.

REMARKS.—It was to this group that Salter first applied the name *Brongniartia*, choosing *H. bisulcatus* as the type-species. The differentiation in structural characters from *Synhomalonotus* is much more marked than in *Eohomalonotus*, particularly in the pygidium, and all the members of this third subgenus occur on higher horizons than those of the first subgenus, to which it is, however, closely related.

4. *Trimerus*, Green.

Head-shield more or less triangular and elongated. Facial sutures uniting anteriorly close to but inside margin in a more or less pointed arch, not forming a continuous regular curve, and posteriorly cutting genal angles. Pre-glabellar area well developed. Glabella subconical, occasionally lobed. Thorax with very broad axis and indistinct trilobation. Pygidium composed of many segments, triangular, elongated, subcylindrical, ending in a produced acumination; trilobation faint; doublure very narrow at sides, widening at tip.

TYPE.—*H. delphinocephalus* (Green).

RANGE.—Silurian (Wenlock).

DISTRIBUTION.—Northern Europe, North America, Australia.

EXAMPLES.

H. cylindricus, Salt.
H. Harrisoni, McCoy.
H. vomer, Chapman.[1]

REMARKS.—Though in point of stratigraphical succession this subgenus follows immediately on that of the *H. bisulcatus* type, yet the pygidium represents an almost entirely new and independent form, and the facial sutures show by their angular junction in front the nature and origin of the continuous curved commissure in the earlier sections. There is no direct derivation from the Ordovician forms, but perhaps links, though at present undiscovered, existed in Llandovery times.

5. *Kœnigia*, Salter.

Head-shield transverse, broad, short. Epistome projecting in front as median process; anterior lateral angles of head-shield angulated forwards, the three together making the margin tricuspid. Facial sutures bending suddenly inwards near anterior margin and uniting in a straight or concave transverse commissure with small median point; posterior branches of facial sutures bent back suddenly to cut lateral margins nearly at genal angles. Paraglabellar areas distinctly marked. Pre-glabellar area very narrow. Thorax with trilobation almost obsolete; axis very broad, scarcely defined. Pygidium composed of many segments, elongated, acuminate, triangular, with smooth pointed posterior process; axis nearly

[1] Chapman, Proc. Roy. Soc. Victoria, vol. xxiv, N.S., pt. ii, p. 298, pl. lxii, figs. 2, 3; pl. lxiii, figs. 1, 2, 1912; Etheridge & Mitchell, Proc. Linn. Soc. N.S.W., vol. xlii, pt. iii, p. 506, 1917.

obsolete, but segmentation of axis and pleuræ distinct. Doublure widening posteriorly.

TYPE.—*H. Knighti*, König.
RANGE.—Silurian (Ludlow).
DISTRIBUTION.—Northern Europe.
EXAMPLE.—? *H. Johannis*, Salt.

REMARKS.—This is undoubtedly a highly specialized group in the genus. A similar sudden bend in the anterior course of the facial sutures is found in *Digonus* (q.v.), and the tendency to a projection of the epistome is seen less developed in *Burmeisteria* (q.v.). The whole head-shield of the type-species is, however, marked by very unusual modifications. It is doubtful if *H. Johannis* can be closely associated with it, in spite of its tricuspid front, as the pre-glabellar portion is different; but the pygidia of the two species are very similar. As regards the thoracic and pygidial characters of *Kœnigia* it is easy to see their general resemblance to *Trimerus*. The specimens of the type-species in the Ludlow Museum which I have been privileged to examine by the kindness of the Curator exhibit the characteristic features with great clearness, being unusually well preserved.

6. *Burmeisteria*, Salter (sens. restr.).

Head-shield more or less triangular. Facial sutures convergent anteriorly and uniting by a double sigmoidal commissure close to front margin, and posteriorly cutting lateral margins in front of genal angles. Pre-glabellar area well developed. Paraglabellar areas distinct. Glabella occasionally lobed. Epistome projecting in front of anterior margin of head-shield as median pointed process. Pre-sutural area very narrow. Thorax with wide, ill-defined axis; trilobation indistinct. Pygidium triangular, acuminate, strongly convex from side to side, composed of many segments; axis and pleuræ more or less distinct. Surface of head-shield, thorax, and pygidium frequently ornamented with more or less regularly disposed large tubercles or spines.

TYPE.—*H. Herscheli* (Murchison).
RANGE.—Lower Devonian.
DISTRIBUTION.—South Africa, South America (including Falkland Islands).

EXAMPLES.

H. quernus, Lake.	*H. agrestis*, Schwarz.
H. colossus, Lake.	*H. horridus*, Schwarz.
H. perarmatus, Frech.	*H. lex*, Schwarz.
H. hippocampus, Schwarz.	*H. noticus*, Clarke.

REMARKS.—This subgenus appears to be limited to the Southern Hemisphere. As far as the thorax and pygidium are concerned, its relations are with *Trimerus*, but the anterior course of the facial sutures seems intermediate between *Trimerus* and *Kœnigia*. The spinosity, which is very irregularly developed in the species, cannot have as much importance attached to it as some authors have maintained.

7. *Digonus*, Gürich.

Head-shield transverse or subtriangular. Middle-shield with anterior lateral angles rectangular, obtuse, or projecting, and with anterior margin truncate, straight, or slightly concave. Facial sutures

bent in suddenly near front margin and uniting in continuous transverse commissure. Pre-glabellar area well developed. Glabella short, subquadrate, or oblong. Thorax with trilobation usually distinct and well marked. Pygidium triangular, elongated, acuminate, more or less pointed behind, composed of many segments; trilobation generally well marked. Surface of thorax and pygidium occasionally scabrous or tuberculated, but not spinose.

TYPE.—*H. gigas*, Roemer.

RANGE.—Lower Devonian.

DISTRIBUTION.—Rhenish area, France, ? England, ? Argentina.

EXAMPLES.

H. rhenanus, Koch.
H. scabrosus, Koch.
H. ornatus, Koch.
H. Le Hiri, Barrois.[1]
? *H. goniopygæus*, Woodw.
? *H. Kayseri*, Thomas.[2]

REMARKS.—The strange course of the facial sutures in their transverse union is somewhat like that of *Kænigia* and *Dipleura*, but the pygidium is closely similar to that of *Burmeisteria*. The trilobation of the thorax is, however, more distinct than in the latter. The shape of the glabella is unusual. We are not acquainted with the true anterior margin of the head-shield, and know nothing about the epistome. It is very uncertain if the common but imperfectly known species *H. armatus*, Burm., belongs to this subgenus (see below).

8. *Burmeisterella*, nom. prop.

Head-shield subtriangular, produced anteriorly into upturned prora formed by epistome and bounded by epistomal sutures. Pre-sutural area large. Facial sutures bend in suddenly in front and unite by transverse commissure close to anterior end of glabella. Pre-glabellar area narrow. Thorax with well-defined cylindrical axis, of less width than pleural portions; trilobation distinct. Pygidium semi-oval, rounded, with regular entire margin (in one species provided with pair of short terminal spines); axis narrow, elongated, distinct; composed of many segments; pleuræ distinct. Surface of glabella and of thoracic and pygidial axes ornamented with regularly disposed pairs of large tubercles or spines.

TYPE.—*H. elongatus*, Salt.

RANGE.—Lower Devonian.

DISTRIBUTION.—Devonshire, ? Rhenish area.

EXAMPLES.

H. Champernownei, Woodw.
H. bifurcatus, sp. nov.
? *H. aculeatus*, Koch.[3]
? *H. armatus*, Burm. (head only).

REMARKS.—Of the type-species we only know the pygidium, but the very closely allied species *H. Champernownei* and *H. bifurcatus* from the same locality and horizon help us to complete the above definition. The regular rounded contour, semi-oval shape, well-defined narrow axis, and regularly paired tubercles of the pygidium

[1] Barrois, Bull. Soc. Géol. France, ser. III, vol. xiv, p. 687, pl. xxxiii, fig. 5, 1886.

[2] Thomas, Zeitschr. deut. geol. Gesell., Bd. lvii, p. 145, pl. ix, figs. 5, 6, 1905.

[3] Koch, op. cit., p. 21, pl. i, fig. 7.

sufficiently distinguish this subgenus from the typical *H. Herscheli* group. The large pre-sutural area and upturned prora, only known from the specimen of *H. bifurcatus*, sp. nov., in the Sedgwick Museum, are likewise peculiar. But they recall the structure of the head-shield of *Dipleura Dekayi*. With regard to the shape and characters of the pygidium and general well-marked trilobation, we see affinities with the Ordovician *Brongniartella*. The paired tubercles on the glabella and other features of the head-shield of *H. armatus* suggest that this species when completely known may have to be placed in this section. The Rhenish *H. aculeatus* has a pygidium apparently much like that of the new British species *H. bifurcatus*. The only well-known forms are from Devonshire.

9. *Parahomalonotus*, nom. prop.

Head-shield semicircular, transverse; facial sutures uniting in regular wide-arched commissure close to anterior margin. Thorax with axis obsolete and trilobation quite lost. Pygidium rounded, semicircular, or semi-oval, with entire margin; trilobation more or less indistinct, but segmentation well marked; border not crossed by pleuræ. Surface ornamented with coarse tubercles and granules (or smooth).

TYPE.—*H. Gervillei*, De Verneuil.[1]
RANGE.—Lower Devonian.
DISTRIBUTION.—Europe.

EXAMPLES.

H. pradoanus, De Vern.
H. Barratti, Woodw.
H. Hausmanni, Rouault.
? *H. planus*, Sandb.
? *H. lævicauda*, Quenst.
? *H. obtusus*, Sandb.[2]
? *H. multicostatus*, Koch.[3]

REMARKS.—This subgenus is characterized by the regular curved union of the facial sutures close to the anterior margin (reminding us of the conditions in *Eohomalonotus* and *Brongniartella*), by the disappearance of the trilobation in the thorax (as in the *Bumastus* group of *Illænus*), and by the regular rounded outline, obsolescent trilobation but distinct segmentation of the pygidium. It looks as if these characters must be due to reversion, as no Silurian forms are known to connect the Ordovician species with this Devonian group. The four last-mentioned examples in the above list differ from the typical members of this subgenus in several minor respects, especially in being smooth, but for the present may be best referred to this subgenus.

10. *Dipleura*, Green.

Head-shield subtriangular, with large pre-sutural prora. Facial sutures uniting in front of glabella by straight transverse commissure, but continued directly forwards without deviation into the epistomal sutures bounding the prora. Thorax with faint trilobation.

[1] Tchichatcheff, Asie Mineure, Paléont., p. 448, pl. xx, fig. 1, 1866; Bayle, Explic. Carte Géol. France, iv, atlas, pl. ii, figs. 1, 3, 6, 1878.
[2] Sandberger, Verstein. rhein. Schicht. Nassau, t. ii, p. 26, figs. 6–6*d*, 1856.
[3] Koch, op. cit., p. 52, pl. vi, figs. 5–9.

Pygidium triangular, subconical, obtusely pointed behind, with trilobation obsolete or obsolescent and segmentation very faintly marked.

TYPE.—*H. Dekayi*, Green.

RANGE.—Middle Devonian (Hamilton Formation).

DISTRIBUTION.—North America.

REMARKS.—This subgenus seems confined to North America and to be the latest representative of the genus *Homalonotus*. It is extremely doubtful if the Harz species *H. Schusteri*, Roem.,[1] is rightly referred to *Dipleura* by Kayser.[2] The characteristic features of *Dipleura* are the large pre-sutural prora (recalling that of *Burmeisterella*), the straight transverse commissure of the facial sutures (somewhat as in *Digonus*), the direct continuation of the facial into the epistomal sutures, and the obsolete trilobation and nearly obsolete segmentation of the pygidium. The last-mentioned character is, however, also found in *H. lævicauda*, Quenst., attributed provisionally to the preceding subgenus, *Parahomalonotus*.

CONCLUSION.

With regard to the stratigraphical distribution of the above-described ten subgenera of the genus *Homalonotus*, we note that the first three, *Eohomalonotus*, *Calymenella*, and *Brongniartella*, are restricted to the Ordovician, the first one being the earliest; *Trimerus* and *Kænigia* occur only in the Silurian, and all the rest, *Burmeisteria*, *Digonus*, *Burmeisterella*, *Parahomalonotus*, and *Dipleura*, are found in the Devonian. It is clear, therefore, that the climax of development was reached in the Devonian, and it is remarkable that the genus did not survive this period.

The phylogeny of the genus is imperfectly known. We have seen that it may be linked with *Calymene* by means of *Synhomalonotus*, though it must have diverged at an early period, or more probably have originated from a common stock. Within the limits of the genus the relationships of the different subgenera are difficult to trace. There is a considerable morphological gap between the Ordovician and Silurian groups, and transitional forms are at present unknown. The Devonian subgenera fall into two main groups, one of which, comprising *Burmeisteria* and *Digonus*, suggests a connexion with the Silurian subgenera, but on the other hand *Parahomalonotus* suggests reversion to the earlier types. *Burmeisterella* in some respects also points back to Ordovician forms, but it is undoubtedly highly specialized. *Dipleura* may be a modification of the *Digonus* type, and is the latest representative of the genus in any part of the world.

I am much indebted to the authorities of the Sedgwick Museum, Cambridge, the British Museum, the Jermyn Street Museum, the Shrewsbury Museum, and the Ludlow Museum for the opportunities afforded me of examining specimens in their collections.

[1] Roemer, Beitr. z. geol. Kennt. nordw. Harzgeb., iii, t. iii, fig. 20, 1855.

[2] Kayser in appendix to Koch, op. cit., p. 76.

NOTICES OF MEMOIRS.

BIBLIOGRAPHY OF THE GEOLOGY AND ERUPTIVE PHENOMENA OF THE MORE IMPORTANT VOLCANOES OF SOUTHERN ITALY. Compiled by HENRY JAMES JOHNSTON-LAVIS, M.D., D.Ch., M.R.C.S., F.G.S., etc., late Professor of Vulcanology in the Royal University of Naples, assisted by Madame ANTONIA JOHNSTON-LAVIS. 2nd edition, completed, after the author's death, by Miss M. B. STANTON, and edited, with a preface and a short life of the author, by B. B. WOODWARD, F.L.S., F.G.S., of the British Museum (Nat. Hist.). 4to; pp. xxiv + 374, with a frontispiece and a photograph of the author in 1905. London: The University of London Press, Ltd., St. Paul's House, Warwick Square, E.C. 4. 1918.

THE history and *raison d'être* of this important work are set forth by the editor, Mr. B. B. Woodward, in his preface, and thence we extract the following salient facts:—

The "Congrès Géologique International" having arranged to hold its second session at Bologna in 1881, the "Comité d'Organisation" in that town decided, in their *Séance* of March 17th, 1879, to undertake the compilation of a "Bibliographie géologique et paléontologique de l'Italie" as a contribution towards the success of the meeting. For many unavoidable reasons that list was an imperfect one. Still, a very considerable number of works and papers were recorded, the total number of entries amounting to 6,566.

Dr. Johnston-Lavis naturally availed himself of those sections that concerned his special pursuits and set to work to supply deficiencies and to add the titles of further publications as issued. In this he was cordially aided by Mme. Lavis, who, working under her husband's directions, industriously transcribed the fresh titles and incorporated them with the entries from the older bibliography.

By the time that the Geologists' Association paid its visit to Southern Italy in the months of September and October, 1889, the bibliography had grown to almost twice the size, and Lavis happily seized upon the occasion to publish it in 1891 as an appendix to the account of the excursion, which was reprinted from the Proceedings of the Association, the whole thus forming a valuable manual of information on the volcanoes of Southern Italy.

From that time onwards no opportunity was lost for working at this bibliography and endeavouring to render it as complete as such a work can ever be.

When the War broke out, depriving him at once of his practice, he had determined to employ his enforced leisure from professional duties till happier times should return in systematically revising and augmenting the whole bibliography and in ransacking every available source with this object in view.

His tragic death[1] cut this project short, and all the loving labour

[1] GEOL. MAG., 1914, p. 480.

of years of patient research seemed likely to be thrown away had not his family most felicitously conceived the idea of completing the work so far as might be possible and publishing it as a worthy offering to his memory.

Fortunately, this has been rendered practicable through the cordial co-operation of his secretary, who, during recent years, had been closely associated with Dr. Johnston-Lavis in the work and was thoroughly acquainted with his scheme and method. Miss Stanton accordingly continued the researches that had been begun in the Library of the Geological Society of London, where the index catalogue prepared by Mr. C. Davies Sherborn proved invaluable, the Reading Room of the British Museum, and the Libraries in the Natural History Museum, extending them to the Library of the Société Géologique de France, where she met with cordial assistance, especially from the President, M. Maurice Cossmann, and the former President, M. Emmanuel de Margerie, and the Bibliothèque Nationale de France, where, as unhappily customary in that establishment, all spirit of practical help was conspicuous by its absence.

In this way the present bibliography was completed, so far as at present practicable, as regards all the more important volcanoes. To have extended its scope and to have embraced all volcanic records for the region would have entailed many more years of labour, whilst the value of the bibliography would not have been materially increased thereby. Nor has it been possible in all cases to incorporate in their entirety the individual contents of previous bibliographies in the body of the present one. The existence of such sources of reference is, however, duly recorded, and the inquirer will, therefore, be furnished with the necessary clue towards the object of his research.

On account of the War, all access to Dr. Johnston-Lavis' own library was cut off, and hence many entries that might have been completed have perforce had to be included in a less perfect state than could have been wished. The whole bibliography must, therefore, under the circumstances of its production, be leniently judged and regarded as a stage only towards that ideal work one would like to see.

The Editor has to acknowledge much kindly assistance and advice given during the progress of the work by Sir Lazarus Fletcher, LL.D., F.R.S.

The subject-matter has been subdivided, as in the previous edition, according to the different volcanic groups, but some modifications in these have been introduced that approximately follow the author's known intentions in that respect.

Altogether there are in this present edition some 7,350 entries, and since these include references to the fauna, flora, and palæontology of the several districts, in addition to their mineralogy, petrology, vulcanology, etc., the work is obviously one of general interest and utility to all workers in natural science, and should therefore find a place on the shelves of every library of any importance.

REVIEWS.

I.—Ordovician and Silurian Fossils from Yun-nan. By F. R. Cowper Reed, M.A., Sc.D., F.G.S. Palæontologia Indica, N.S., vol. vi, Memoir 3, pp. iv + 69, 8 pls., 1917.

SINCE 1913 we have known that Mr. Coggin Brown, during his exploration of South-western Yun-nan a few years previously, had collected some Lower Ordovician and Silurian fossils. Dr. Cowper Reed's complete description of these is at last published, with excellent illustrations by Mr. T. A. Brock, and with determinations of the graptolites by Dr. Gertrude Elles.

The Ordovician fossils are from three localities: Pu-piao, La-mêng, and Shih-tien. It was from Pu-piao that Loczy on the Szechenyi expedition obtained cystid plates referred by him to *Hemicosmites*. The rocks here are mudstones with a calcareous band; all are probably of Llandeilo age, and the mudstones, at any rate, contain *Didymograptus murchisoni* and its normal associates. The rock at La-mêng resembles that of the Hwe Mawng Beds in the Northern Shan States of Burma, and the few poorly preserved fossils are consistent with that horizon. Five types of rock from Shih-tien probably represent as many beds. The contained fossils show general agreement with the fauna of the Sedaw Beds in the Naungkangyi series of the Northern Shan States, and Dr. Reed inclines to correlate the beds with Schmidt's stages B and C (*Orthoceras*, *Echinosphæra*, and *Chasmops* Limestones) of the Baltic region.

The Silurian beds of Shih-tien consist of two kinds of shale, with two different assemblages of graptolites of Llandovery age. The higher horizon belongs to the base of the zone of *Monograptus sedgwicki*, and its most abundant fossil is *M. lobiferus*. The lower horizon abounds in *Climacograpti*, not specifically determinable, with other specimens suggesting the zone of *Orthograptus vesiculosus* or the base of the *Monograptus gregarius* zone. These two horizons yield no fossils other than graptolites.

Of the Ordovician fossils the most important are the Cystids, in respect to number both of specimens and of species and in respect to novelty, there being described two new genera and ten new species. The genera are *Sinocystis* and *Ovocystis* (n.gg.), *Pyrocystis*, *Eucystis*, *Sphæronis*, *Echinosphæra*, *Heliocrinus*, *Caryocystis*, *Echinoencrinus*, and *Caryocrinus*. Crinoids are represented only by one specimen of the fossil which Dr. Reed calls *Camarocrinus asiaticus*. Of Brachiopods there are the genera: *Philhedra* (1 n.sp.), *Orthis* (1 n.sp.), *Hemipronites* (1 n.var.), *Rafinesquina* (?), *Plectambonites*, *Streptis*, and *Porambonites*. Lamellibranchs are represented by undetermined species of *Ctenodonta* and *Conocardium*; and Gastropods by doubtfully determined species of *Holopea*, *Raphistoma*, *Bellerophon*, *Cyrtolitina*, and *Hyolithes*. Cephalopods are numerous, especially at Shih-tien, and belong to *Endoceras*, *Orthoceras* (1 n.sp.), *Jovellania*, *Cameroceras* (?), *Actinoceras*, *Spyroceras* (?), *Trocholites* (1 n.sp.), *Lituites*, and *Tarphyceras* (?). The few and often fragmentary remains of Trilobites are referred to *Harpes*, *Remopleurides*, *Asaphus*,

Ogygites (1 n.sp.), *Illænus* (6 spp., of which 1 is new), *Nileus*, *Bathyurus* (1 n.sp.), *Lichas*, *Calymene* (1 n.sp.), and *Pliomera* (1 n.sp.).

The relations of the faunas from all three localities, apart from obvious similarity to those of the Shan States, are in Dr. Reed's opinion closest with those of North-West Europe. This is perhaps more noticeable in the cephalopods than in the cystids. The Echinosphæra Limestone of the Baltic Provinces and Scandinavia certainly has an "abundance of cystideans", but the general composition of its cystid fauna is not much like that of Shih-tien. On the contrary, connection with North America is closely indicated by some of the new cystids, possibly by the so-called *Camarocrinus*, and certainly by such cephalopods as *Actinoceras* cf. *bigsbyi* and the *Jovellania*.

The descriptions give sufficient detail, and Dr. Reed seems to have extracted a good deal of information from material sometimes unpromising. Dr. Reed's knowledge of these Ordovician faunas is undoubtedly "extensive", but he might realize that it is also "peculiar", and might sometimes make matters easier for his less learned colleagues by stricter attention to the technical presentation of his results. Thus, he gives a full description, with five figures, of *Hemipronites giraldi* var. nov. *yunnanensis*; but he entirely fails to indicate in what it differs from the original species-form. Similarly, in addition to the page-and-half description of *Ogygites yunnanensis*, n.sp., it would have been well to furnish a brief specific diagnosis; a few other species of the genus are mentioned, but the differences are indicated for only two of them. A little more attention to matters of this kind would be a great help to the weaker brethren, and would add to the gratitude they feel for these interesting accessions to our knowledge from the outermost fringes of empire.

II.—The Glacial Geology of Norfolk and Suffolk. By F. W. Harmer, F.G.S. pp. 26, with 7 figures and a contoured map. London: Jarrold & Sons; Dulau & Co., Ltd., 37 Soho Square, W. 1.

IN this small book, reprinted from the Transactions of the Norfolk and Norwich Naturalists' Society, vol. ix, Mr. Harmer gives a summary, written in a somewhat popular style, of his well-known work on the glacial deposits of East Anglia, and of the important conclusions that he has been able to draw as to the sequence of events in that area during the Pleistocene period. For more than fifty years Mr. Harmer has devoted most of the leisure of a busy life to this subject, and his conclusions are naturally deserving of the most careful consideration.

The lower part of the glacial series is classed under the collective name of the North Sea Drift, including the Cromer Till and Contorted Drift of other authors. This contains numerous far-travelled erratics from Scotland and Scandinavia, of quite unmistakable types, and the source of this material is not a matter of controversy. The brickearths of the interior of Norfolk may be taken to represent the *moraine profonde* of the North Sea ice-sheet, while the Cromer

ridge is its terminal moraine at some stage of the retreat. But when we come to consider the higher members of the glacial series the question is not quite so simple. It is quite clear that in East Anglia there are two boulder-clays, divided by sands and gravels; the most notable feature of the upper one, which is equivalent to the Chalky Boulder-clay of the Midlands, is the presence of enormous quantities of Kimeridgian material, which can only have come from the north-west, that is in a direction more or less at right angles to the flow of the North Sea Glacier. Mr. Harmer considers that this ice, his Great Eastern Glacier, originated in the mountains of the North of England and flowed down the Vale of York, across Lincolnshire, and over the Fenland, being reinforced by lateral glaciers descending from the Pennine valleys and by ice coming up the Humber gap from the North Sea. Hence it contains a great variety of Jurassic and Cretaceous erratics, especially Kimeridge Clay, Neocomian sandstones, hard Chalk, and characteristic tabular flints from Lincolnshire, the latter being very abundant and easy to recognize. This second glacier ploughed up and incorporated in its own deposits much of the North Sea Drift, so that the westward extension of the latter is ill-defined. This hypothesis explains in a satisfactory manner the abundance of Kimeridgian material in Norfolk and Suffolk, which is difficult or impossible to account for in any other way. Granting the fundamental assumption that land ice can move in any direction for any distance over a more or less flat surface, the rest is easy. It is also shown by a study of the relation of the drifts to the valleys of Norfolk that great denudation took place between the deposition of the two boulder-clays, and this fact is of much interest in connexion with the question of the occurrence of inter-glacial periods, since a long interval of time is indicated, which may correspond to one of the warm periods of Penck and Brückner. The origin of the plateau gravels and valley gravels of the area may also be ascribed to the torrential waters set free during the later stages of the melting and retreat of the ice.

It will thus be seen that this book contains in a very condensed form a summary of an enormous amount of work and presents problems of absorbing interest, which will probably continue to occupy the attention of geologists for a long time to come.

R. H. R.

III.—The Outlook for Iron. By J. F. Kemp. From the Smithsonian Report for 1916, pp. 289–309. Washington, 1917.

IN these few pages the author gives a resumé of our present knowledge of the reserves of iron-ore still available, with special reference to the United States. The general conclusion is that while the supplies of high-grade ore are distinctly limited, the reserves of low-grade ore are practically inexhaustible. The output of ore from the Lake Superior region, for example, cannot be kept up to the present production with a minimum of 50 per cent of iron for more than fifty years, while on a similar basis the Clinton ores of Alabama, Tennessee, and Georgia can be considered as assured for a little over 100 years. Hence for a successful continuance of iron-smelting in

the United States one of three things must occur: either a great improvement in metallurgical processes, rendering the employment of low-grade ores remunerative, or some change of economic conditions leading to a similar result, or the great development of foreign sources of supply accompanied by cheap transport. In conclusion, some attention is paid to the amount of coke likely to be available in the future for iron-smelting; no apprehension is felt of any failure in this quarter, since apparently the fuel will last longer than the iron-ore.

R. H. R.

IV.—Dry Land in Geology. By A. P. Coleman. Smithsonian Report for 1916, pp. 255–72.

THIS is a reprint from the Bulletin of the Geological Society of America of the Presidential Address for 1915. It is pointed out that all the earlier geologists confined their attention almost exclusively to marine deposits, because these contain abundant fossils, whereas in terrestrial deposits they are scarce or wanting. It is only of recent years that the importance of the latter group has been recognized. The chief types are arid and glacial respectively; arid deposits have now been found or imagined in all systems except the Ordovician and Jurassic, and it is possible that the idea has been overdone, since it is not proved that all red sandstones were necessarily formed in deserts. A careful study also shows a remarkably close association between arid and glacial deposits; at first sight this seems improbable, but it is actually occurring in the world to-day. The primary question of the origin of the land remains unanswered; we can only suppose it to be due on isostatic principles to an accidentally uneven distribution of density in the globe, and unless we are prepared to admit flow of rock-material below the crust on a gigantic scale it seems to follow that continents and ocean basins must be on the whole permanent features, and adjustments of the boundaries of sea and land have been confined to the margins of continental masses.

R. H. R.

REPORTS AND PROCEEDINGS.

Geological Society of London.

May 1, 1918.—G. W. Lamplugh, F.R.S., President, in the Chair.

Dr. A. Hubert Cox, M.Sc., F.G.S., delivered a lecture on the Relationship between Geological Structure and Magnetic Disturbance, with especial reference to Leicestershire and the Concealed Coalfield of Nottinghamshire.

Before the lecture, at the request of the President, Dr. A. Strahan, F.R.S., Director of the Geological Survey, briefly outlined the circumstances that had led to an investigation into a possible connexion between geological structure and magnetic disturbances. The magnetic surveys conducted by Rücker and Thorpe in 1886 and

1891 had proved the existence of certain lines and centres of disturbance, but those authors observed that "the magnetic indications appear to be quite independent of the disposition of the newer strata", and he (the speaker) had not been able to detect any obvious connexion with the form and structure of the Palæozoic rocks below. In 1914–15 a new magnetic survey was made by Mr. G. W. Walker, who confirmed the existence of certain areas of disturbance. It was suggested that the effects might be due to concealed masses of iron-ore, and the matter was referred to the Conjoint Board of Scientific Societies, who appointed an Iron-Ores Committee to consider what further steps should be taken. The Committee recommended that attention should be concentrated on certain areas of marked magnetic disturbance, and that a more detailed magnetic survey of these areas, accompanied by a petrological survey and an examination of the magnetic properties of the rocks of the neighbourhood, should be made. He (the speaker) had been approached with a view to the petrological work being undertaken by the Geological Survey, and it had been arranged by the Board of Education, with the consent of H.M. Treasury, that a geologist should be temporarily appointed as a member of the staff for the purposes of the investigation. Dr. Cox had received the appointment, and the lecture which he was about to deliver would show that results of great significance had been obtained by him. The new magnetic observations had been made by Mr. Walker, and the examination of the specimens collected, in regard to their magnetic susceptibility, had been conducted by Prof. Ernest Wilson.

Dr. Cox then described the selected areas, which lay on Lias and Keuper Marl between Melton Mowbray and Nottingham, and in the neighbourhood of Irthlingborough, where the Northampton Sands are being worked as iron-ores. The Middle Lias iron-ores, consisting essentially of limonite, which crop out near Melton Mowbray, have been proved incapable, by reason of their low magnetic susceptibility, of causing disturbances of the magnitudes observed, while the distribution of the disturbances showed no correspondence with the outcrop of the iron-ores. Nor was any other formation among the Secondary rocks found capable of exerting any appreciable influence. It appeared, therefore, that the origin of the magnetic disturbances must be deep-seated.

Investigation showed that the disturbances were arranged along the lines of a system of faults ranging in direction from north-west to nearly west. The faults near Melton Mowbray have not been proved in the Palæozoic rocks, and, so far as their effects on the Secondary rocks are concerned, they would appear to be only minor dislocations. But farther north, near Nottingham, faults which take a parallel course, and probably belong to the same system of faulting as those near Melton Mowbray, are known from evidence obtained in underground workings to have a much greater throw in the Coal-measures than in the Permian and Triassic rocks at the surface. It appears, therefore, that movement took place along the same lines at more than one period, the earlier and more powerful movement being of post-Carboniferous but pre-Permian age, the

later movement being post-Triassic. Accordingly, it is probable that the small dislocations in the Mesozoic rocks indicate the presence of important faults in the underlying Palæozoic.

The faults can only give rise to magnetic disturbances if they are associated with rocks of high magnetic susceptibility. It is known from deep borings that the concealed coalfield of Nottinghamshire extends into Leicestershire, but how far is not known. Deep borings have proved that intrusions of dolerite occur in the Coal-measures at several localities in the south-eastern portion of the concealed coalfield and always, so far as observed, in the immediate vicinity of faults. It has been established that dolerites may exert a considerable magnetic effect; and the susceptibility of those that occur in the Coal-measures is above the general average. Further, no other rocks that are known to occur, or are likely to occur under the area, have susceptibilities as high as the dolerites found in the Coal-measures. These facts suggest the possibility of the occurrence of dolerites intrusive into Coal-measures beneath the Mesozoic rocks of the Melton Mowbray district.

The distribution of the dolerites actually proved, and of those the presence of which is suspected by reason of the magnetic disturbances, appears to be controlled by the faulting. Moreover, whereas the character of the magnetic disturbances is such that it would not be explained by a sill or laccolite faulted down to the north, in the manner demanded by the observed throw of the principal fault, it would be explained by an intrusion that had arisen along the fault-plane. The faulting itself is connected with a change of strike in the concealed Coal-measures, and the incoming of doleritic intrusions in the concealed coalfield, in contrast with their absence from the exposed coalfield, appears to depend upon the changed tectonic features. The change of strike is apparent, but to a less degree, in the Mesozoic rocks which, in the neighbourhood of Melton Mowbray, have suffered a local twist due to the development of an east-and-west anticlinal structure.

In view of the evidence that later movements have, in this district, followed the lines of earlier and more powerful movements, it appears possible and even probable that this post-Jurassic (probably post-Cretaceous) anticline is situated along the line of a more pronounced post-Carboniferous but pre-Permian anticline. In this connexion the isolated position of Charnwood Forest has a considerable significance. The Forest is situated on the prolongation of the east-and-west line of uplift, and just at the point where this uplift crosses the line of the more powerful north-westerly and south-easterly (Charnian) uplift. Where the two lines of uplift cross the elevation attains its maximum, and the oldest rocks appear.

The main line of faulting and of magnetic disturbance is parallel with and on the northern side of the east-and-west anticline, and the faulting is of such a nature that it serves to relieve the folding while accentuating the anticlinal structure. It is possible that this belt of magnetic and geological disturbance marks the southern limit of the concealed coalfield. The results obtained by joint magnetic and geological work have thus served to emphasize the real

importance of a structure which, when judged merely from its effects on the surface rocks, appears to be of only minor importance.

A further series of observations was carried out on the Jurassic iron-ores of the Irthlingborough district of Northamptonshire. The ores occur in the form of a nearly horizontal sheet of weakly susceptible ferrous carbonate partly oxidized to hydrated oxides. They give rise to small magnetic disturbances which are quite capable of detection, and these may be of use in determining the boundaries of the sheets in areas not affected by larger disturbances of deep-seated origin.

The results obtained by the joint magnetic and geological work in the two areas show that this method of investigation may be used to extend our knowledge of the underground structure. It appears also that an extension of the method to other parts of the country would yield information of considerable scientific and economic importance.

Geological maps were exhibited by Dr. A. Hubert Cox, M.Sc., F.G.S., in illustration of his lecture.

CORRESPONDENCE.

RICHARD HALL.

Sir,—Excellent notices have appeared recently in *Nature* and in the Geological Magazine calling attention to the important work accomplished by Mr. Richard Hall, now retired, during his thirty-eight years of service in the Geological Department of the British Museum as a "preparer of fossils".

Sufficient stress has not been laid on Mr. Hall's skill in the development of invertebrate fossils, also in the preparation of delicate microscopic objects and the cutting and polishing of rock-surfaces exhibiting organic structures. Special attention might be called to the large series of sections of Monticuliporoid corals figured and described by Dr. Foord, Mr. Robert Etheridge, jun., and the late Professor H. A. Nicholson.

He also made the large sections on glass of the Palæozoic corals now in the Geological Department, which enable the student to study with ease the internal characters of the Cyathophylloid and other groups. Later he prepared microscopic sections of Foraminiferal rocks which proved of material assistance in researches in the geology of Africa, Madagascar, New Guinea, Borneo, etc. It is a surprising fact that an operator who could so successfully disentomb from its matrix a great reptile like the *Pariasaurus* should have been equally proficient in the preparation of delicate sections of microscopic objects.

R. Bullen Newton.

MISCELLANEOUS.

Ludlow Museum.—We are glad to learn that the Ludlow Natural History Society has received a bequest of £200 from the late Mrs. Agnes Mary White, daughter of the well-known geologist, the late Mr. Humphry Salwey, of The Cliff, Ludlow. It is a welcome contribution to the funds of an important institution which has suffered much from lack of means during recent years.—A. S. W.